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14. ABSTRACT
This Test Operations Procedure (TOP) establishes procedures for conducting ground mobility subtests concerned with the interactions between the vehicle and soil, surface geometry, and vegetation in a humid tropic environment. These procedures can be applied with appropriate modifications to other environments.

15. SUBJECT TERMS
Tropics, VCI, ground mobility, vegetation, RCI, soil

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U.S. ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

*Test Operations Procedure 02-2-817A 27 August 2014
DTIC AD No.

TROPIC TESTING OF VEHICLES

*This TOP supersedes TOP 02-2-817, Tropic Testing of Vehicles, dated 1 June 1986

1. SCOPE.

a. This Test Operations Procedure (TOP) establishes procedures for conducting ground mobility subtests concerned with the interactions between the vehicle and soil, surface geometry, and vegetation in a humid tropic environment. These procedures can be applied with appropriate modifications to other environments.

b. The following vehicle mobility subtests are covered in this TOP:

SUBTESTS	CODE
Soil Tests	
One-Pass Vehicle Cone Index (VCI)	A
Drawbar Pull	B
Motion Resistance	C
Acceleration/Deceleration	D
Surface Geometry Tests	
Slope Negotiation	E
Discrete Obstacle	F
Vegetation Tests	
Single-Tree Override	G
Multiple-Tree Override	H
Grassland Override	I

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

The tests established herein are to be conducted in the natural environment and the only necessary requirements are suitable test areas. Table l summarizes the terrain and vegetation characteristics for the test site selected previously for tropic tests of vehicles. Other areas may be used for testing if they have similar characteristics and are consistent with the criteria of the tests being conducted. Specific details regarding test site parameters are provided in Appendix C.

TABLE 1. TEST SITE CHARACTERISTICS

Test Area					Afobaka, Suriname
Universal Transverse Mercator (UTM) Coordinates	Zone				21
	North				730930
	East				553600
Size of Site (hectares)					3,255
Climatic Conditions	Operational	Constant High Humidity	Ambient Air Temperature °C (°F)	Daily Low	24 (75)
				Daily High	
			Solar Radiation W/m^2(Bph)		Negligible
			Ambient Relative Humidity %RH		95 to 100
		Variable High Humidity	Ambient Air Temperature °C (°F)	Daily Low	26 (78)
				Daily High	35 (95)
			Solar Radiation W/m^2(Bph)		0 to 970 (0 to 307)
			Ambient Relative Humidity %RH		100 to 74
	Storage and Transit	Constant High Humidity	Induced Air Temperature °C (°F)	Daily Low	Nearly Constant 27 (80)
				Daily High	
			Induced Relative Humidity %RH		95 to 100
		Variable High Humidity	Induced Air Temperature °C (°F)	Daily Low	30 (86)
				Daily High	63 (145)
			Induced Relative Humidity %RH		75 to 19
Soil Characteristics	Unified Soil Classification System (USCS)			0-15 cm (0-6 inches)	Clay of low plasticity (CL), clayey sand (SC)
				15-30 cm (6-12 inches)	Clay of low plasticity (CL), clayey sand (SC)
	Cone Penetrometer (kg/cm^2)			0-15 cm (0-6 inches)	16.2-40
				15-30 cm (6-12 inches)	17.5-40.7
Stiffness (millinewton/meter (mN/m))				0-15 cm (0-6 inches)	4.2-25.5
				15-30 cm (6-12 inches)	4.9-21.2
Slope (percent)					0-20
Vegetation Characteristics	Type				Grasses (GR), mixed secondary growth (MXSG)
	Stem Density (stems/m^2)				Not applicable
	Height (meters)				Not applicable
Type Test That Site Is Recommended For (per paragraph 1.b)					A, B, C, D, E, F, G, H, I

2.2 Instrumentation.

Instrumentation and accuracies/capacities required for mobility subtests are described below:

2.2.1 One-Pass VCI.

Devices for Measuring	Permissible Error of Measurement**a
Cone penetrometer	21.1 kg/cm^2; ±10%
Soil moisture/density sampler	5.08-cm diameter, thin-walled sample tube
Remolding apparatus	Accuracy is determined by cone penetrometer

2.2.2 Drawbar Pull Test.

Devices for Measuring	Permissible Error of Measurement**a
Load cell	Capacity depending on weight of test vehicle, ±1%
Distance measuring device	±1%
Wheel revolution counter	±1/4 revolution
Data recorder with time code generator	Multichannel/± 0.1 second
Cone penetrometer	21.1 kg/cm^2; ±10%
Remolding apparatus	Accuracy is determined by cone penetrometer

2.2.3 Acceleration/Deceleration Test.

Devices for Measuring	Permissible Error of Measurement**a
Distance measuring device	±1%
Timing device	±0.1 second
Speed measuring device	±30.5 cm per second
Wheel revolution counter	±1/4 revolution
Data recorder with time code generator	Multichannel/± 0.1 second
Cone penetrometer	21.1 kg/cm^2; ±10%
Remolding apparatus	Accuracy is determined by cone penetrometer

**a The permissible error of measurement for instrumentation is the two-sigma value for normal distribution; thus, the stated errors should not be exceeded in more than one measurement of 20.

2.2.4 Slope and Obstacle Test.

Devices for Measuring	Permissible Error of Measurement**[a]
Total station	±15 minutes
Surveying rod	±0.5 centimeter
Distance measuring device	±1%
Data recorder	Multichannel
Abney level	±0.5 degree
Cone penetrometer	21.1 kg/cm^2; ±10%
Remolding apparatus	Accuracy is determined by cone penetrometer

2.2.5 Motion Resistance and Override Tests.

Devices for Measuring	Permissible Error of Measurement**[a]
Load cell	Capacity depending on weight of test vehicle, ±1%
Distance measuring device	±1%
Data recorder with time code generator	Multichannel/± 0.1 second
Cone penetrometer	21.1 kg/cm^2; ±10%
Remolding apparatus	Accuracy is determined by cone penetrometer

2.2.6 Vegetation Override Test.

Devices for Measuring	Permissible Error of Measurement**[a]
Load cell	Capacity depending on weight of test vehicle, ±1%
Distance measuring device	±1%
Data recorder with time code generator	Multichannel/± 0.1 second
Stem diameter tape	±0.3 cm
Cone penetrometer	21.1 kg/cm^2; ±10%
Remolding apparatus	Accuracy is determined by cone penetrometer

**[a] The permissible error of measurement for instrumentation is the two-sigma value for normal distribution; thus, the stated errors should not be exceeded in more than one measurement of 20.

3. REQUIRED TEST CONDITIONS.

3.1 Facilities.

Based on a previous methodology investigations***[1,2], and testing experience, test areas suitable for use in conduct of tropic tests of vehicles could be classified according to their suitability for use of tests described in the following paragraphs. Table l presents this information for a currently available suitable test area, and should be used by test personnel in selection of optimum test sites. This, however, does not preclude selection of other test sites provided they have characteristics that are consistent with the criteria of the particular test involved. Appendix C defines the test site parameters. Factors to be considered in site selection are discussed further in this section.

3.1.1 One-Pass VCI.

a. This test is conducted to determine the minimum soil strength required for a ground crawling vehicle to negotiate one pass over fine-grained soil (clays and silts). Experimental VCI is not determined for clean sands. Soil strength is defined in terms of Rating Cone Index (RCI) in the critical layer which for most vehicles is at the 0-to-6-inch (0 to 15 cm) depth for one-pass VCI (VCI_1) and 6-to-12-inch (15 to 30 cm) depth for 50-pass VCI (VCI_{50}). Thus, the RCI is the soil strength at which a vehicle can complete one pass and is the VCI for that vehicle. The VCIs can also be computed for one and fifty passes using the methods and techniques described in Appendix B.

NOTE: $\mathrm{RCI} = \mathrm{Cone\ Index\ (CI)\ x\ Remolding\ Index\ (RI)}$ for the same soil layer

b. Test sites selected should have uniform soil strengths along the length of the test lane in the critical layer [0 to 6 inch (0 to 15 cm)] and the underlying layer [6 to 12 inch (15 to 30 cm)]. Uniformity within the test lane can be determined after examining Cone Index (CI) data taken at several locations along the test lane. Test lanes should be level, free of heavy vegetation and surface irregularities, and at least 30 meters (100 feet) in length. A range of soil strength bracketing the computed VCI is necessary to experimentally establish VCI. For example, if the computed VCI is 25, then the average RCI in the 0 to 6 inch (0 to 15 cm) layer of the test lane selected should range from 20 to 30 RCI.

c. To shorten testing time, test sites should have test lanes oriented so that the test vehicle proceeds from firm to soft soil until it is immobilized. Soil strength (CI and RI) data are taken along both sides of the vehicle to determine the RCI at which the vehicle became immobilized.

***Superscript numbers correspond to Appendix E, References.

3.1.2 Drawbar Pull.

a. This test is conducted to obtain data to determine the maximum drawbar pull that a vehicle can achieve on a given soil strength defined in terms of RCI for fine-grained soil and CI for coarse-grained soils (clean sands). The critical layer in both cases is the 0 to 6 inch (0 to 15 cm) depth. Previous tests have indicated that the maximum drawbar pull for most vehicles occurs at about 20-percent wheel or track slip, except for track vehicles which achieve their maximum drawbar pull at about 40-percent slip in coarse-grained soils. Several drawbar pull tests are conducted on a range of RCIs above the minimum required to support the test vehicle. From these tests, drawbar pull and soil strength relation is established. The maximum drawbar pull coefficient (drawbar pounds divided by the vehicle's test weight) that a vehicle can develop on a given soil strength closely approximates the tangent of the maximum angle that the vehicle can negotiate on the same soil strength.

b. Areas required for these tests are those in which 50 to 75 meter-long test lanes can be established in smooth, level, relatively undisturbed surfaces free of heavy vegetation and containing a range of soil strengths.

3.1.3 Motion Resistance.

This test determines the force required to overcome the motion resistance of the test vehicle when operated over a range of soil strengths. Thirty meter-long test lanes with uniform terrain conditions similar to VCI and drawbar pull tests are required. The test data are used to develop soil strength and motion resistance relations for the same soil types and strength ranges as for the drawbar pull tests. Usually they are conducted in the same test lane as the drawbar pull tests except that in the motion resistance test the vehicle is offset to straddle the ruts.

3.1.4 Acceleration/Deceleration.

This test determines the capability of a vehicle to accelerate and decelerate on a variety of surface conditions. Thirty to ninety meter-long test lanes are required, depending on the maximum speed a vehicle is expected to achieve before decelerating. For example, if the average RCI of the test lane is 20 points above the VCI, the test lane can be about one-half as long as if the test lane RCI were 100 points above the VCI. The soil and surface conditions required for this test are similar to the requirements described above for the drawbar pull test.

3.1.5 Slope Negotiation.

This test determines the slope performance of the vehicle of various surface conditions. It requires slope conditions that vary from shallow to steep, having uniform surface and soil strength conditions.

3.1.6 Discrete Obstacle.

This test determines the capability of a vehicle to negotiate naturally occurring obstacles such as ditches, logs, mounds, and gullies. Suitable natural obstacles should be used and they should be selected so that appropriate approach and departure avenues can be prepared if necessary.

3.1.7 Tree Override.

This test measures the amount of force required to push over and override trees of various stem diameters and branching structures. Approach lanes should extend into the jungle, and be cut as required. During the single tree override tests, all undergrowth is cleared to allow easy movement and positioning of the vehicle, and to remove the resistive force produced by adjacent vegetation. The jungle site chosen should have an ample number of trees with diameters at chest height (DBH) of 2.5 to 25 cm (1 to 10 inches). The surface of the site should be nearly smooth, level, and with sufficient soil strength to enable test vehicles to develop near maximum traction. The site should also allow ample room for positioning of test and winching vehicles. This is discussed in more detail in Section 5.

3.1.8 Grassland Override.

This test is conducted in much the same manner as the Motion Resistance test (paragraph 3.1.3), but the basic difference is that the force above the level of motion resistance is a result of standing grass. Grass areas with 46 meters (150 feet) of smooth level lanes are needed. In tall grasses, visibility will limit the speed at which the driver will advance his vehicle; therefore, the length of the test lane can be reduced to 23 meters (75 feet). In overriding tall grasses they may become wrapped around the drive shaft causing some difficulty to light vehicles. In dry grasses the exhaust system could ignite a grass fire.

3.2 Equipment.

Vehicles used in these tests should be loaded to the recommended cross-country payload, be in good electrical/mechanical condition, and have the recommended tire pressure for the type of terrain to be traversed. Safety features considered necessary should be installed such as a protective cage over the driver for the tree override test. Tests should not be initiated until the engine has reached operating temperature.

3.3 Instrumentation.

Proper calibration of each instrument should be verified prior to beginning each test. No additional instrument preparations are needed for the following tests: One-Pass VCI, Slope Negotiation, or Discrete Obstacle. Specific instructions are listed below for the remaining tests.

3.3.1 Drawbar Pull.

Connect the load cell in-between the test vehicle and the load vehicle using tow cables. Install the drive wheel or sprocket revolution counter on the test vehicle. Install the load cell amplifier

and the line payout distance measuring device on the load vehicle. Connect all devices to a multichannel data recorder in the load vehicle where all data should be sequenced against an appropriate time-code generator.

3.3.2 Motion Resistance.

Connect the load cell in-between the test vehicle and the winching vehicle using tow cables. Place the load cell amplifier in the winching vehicle.

3.3.3 Acceleration/Deceleration.

Install the drive wheel or sprocket revolution counter, line payout distance measuring device, time code generator, and multichannel recorder on the test vehicle. Connect each device to the multichannel data recorder.

3.3.4 Single-Tree, Multiple-Tree, and Grassland Override.

These test procedures are the same as for Motion Resistance (paragraph 3.3.2).

3.4 Data Required.

3.4.1 One-Pass VCI.

After selection of a suitable test lane, in accordance with instruction in One-Pass VCI (paragraph 3.1.1), collect soil samples before traffic for laboratory analysis and record the data as shown in Table 2, along the test lane.

TABLE 2. ONE-PASS VCI DATA

TYPE OF DATA	SAMPLE POINTS	PURPOSE
Soil sample from the 0 to 6 inch soil layer	Two	Determine soil classification according to USCS
Soil sample from the 0 to 6 inch soil layer	Two	Determine soil moisture content and density
Cone Index	Every three meters at 2-, 4-, 6-, 8-, 10-, and 12-inch depths	Determine soil strength data in expected vehicle tracks
Soil sample from the 0 to 6 inch soil layer	Two or three	Establish RCI for the test lane remolding index at the lowest CI stations in the test lane

3.4.2 Drawbar Pull.

No soil data are collected before traffic. It is recommended to conduct the test run first, then measure the "before traffic soil data" adjacent to the ruts where a good record of maximum

drawbar pull can be obtained. RCI, moisture content and density determination are required for the 0- to 6-inch depth. Samples are required for laboratory analysis of soil classification for the same soil layer.

3.4.3 Motion Resistance.

No pre-test measurements are required. Soil data should be measured after the vehicle tests, adjacent to the site where a good stable record of force required to tow the vehicle was obtained.

3.4.4 Acceleration/Deceleration.

No data needs to be recorded prior to actual test execution. As in drawbar pull above, soil data are taken in a section of the test lane that represents the soil conditions in which the test was run.

3.4.5 Slope Negotiation.

Measure and record the slope along the test lane. The maximum angle that the test vehicle can negotiate the prevailing soil conditions should be determined by available maximum drawbar pull-soil strength relations for the approximate soil type. This is the angle formed between a line passing through the center of gravity (CG) of the vehicle, which is perpendicular to the ground, and a line that passes through the CG to the point on the ground which is perpendicularly beneath the center of the rear axle. This angle is computed as the arctangent d/h where d is the horizontal distance along ground from the point beneath the rear axle and the point perpendicularly beneath the CG, and h is the vertical distance from the ground to the CG. At no time should the slope of a test lane exceed this angle since the test vehicle will probably not negotiate it. The terrain descriptions would include the surface roughness, vegetation cover, and any other condition that may impede the progress of the test vehicle on the slope.

3.4.6 Discrete Obstacle.

Detailed profiles of all obstacles for a distance of 6 meters (20 feet) on each side of the obstacle should be recorded (e.g., depth of ditches, height of logs and rocks, and slope and height of mounds), using standard surveying techniques. Soil sample measurements should be collected in accordance with paragraph 3.4.l, and a photographic record maintained of each obstacle.

3.4.7 Single-Tree Override.

Record the DBH of each tree to be challenged. If the soil is fine-grained, record the cone index and remolding index of the 0- to 6-inch layer. Bulk soil samples should also be taken for the 0- to 6-inch layer for classification and moisture content determination. Record the vehicle identification, bumper height and ground clearance to the nearest centimeter (0.5 inch), and test weight to the nearest 45 kilograms (100 pounds).

3.4.8 Multiple-Tree Override.

Record the data prescribed in paragraph 3.4.7, to include measurements of each tree in the path of the vehicle. Record the distance in inches between each tree and the relative position (x, y coordinate) of each tree. Heavy vines should be included in these measurement records.

3.4.9 Grass Override.

Record the soil parameters outlined in paragraph 3.4.1. In addition, mark off several 1 meter squares (outside the expected vehicle path) and measure stem height (meters) and density (stems/m^2).

4. TEST PROCEDURES.

4.1 Vehicle Mobility Subtests.

These tests should not be conducted during or immediately following rains or anytime there is standing water or puddles on the soil surface because tropical clay soil surfaces are slippery when the surface contains free water. This will minimize traction and invalidate test results. Moreover, all vehicle operators involved in testing should be experienced drivers to minimize the possibility of driver influence. If military personnel are required, ensure a Test Schedule and Review Committee (TSARC) request is submitted within one year from the start of testing or as early as possible. A Safety Release (SR) must be obtained from the U.S. Army Evaluation Center (AEC) prior to using military personnel as test participants.

4.1.1 One-Pass VCI.

A sufficient number of tests should be conducted on soft soils with uniform soil strength to accurately bracket the "go", "no-go" performance. All tests should be conducted with the vehicles being driven through the test lane at an extremely low speed of approximately 3 kilometers/hour (2 miles/hour). In the event of immobilization, the driver should obtain assistance from a retrieving vehicle. If immobilization occurs with little or no sinkage and the underlying soil is firm, the immobilization was probably caused by surface slipperiness. Such an immobilization is not acceptable in determining VCI. Firm clay soils overlain by a thin wet surface layer (vegetation, organic matter, mud, free water) should be suspect for VCI tests because of potential slippery conditions.

4.1.2 Drawbar Pull.

The maximum drawbar pull should be maintained at a constant slip for at least a vehicle length and repeated a minimum of three times on each tested soil strength. The test should be repeated on a sufficient number of soil strengths to establish a drawbar pull soil strength curve. The vehicle should be driven in its lowest gear with drive wheel or track speeds of 3 to 5 kilometers/hour (2 to 3 miles/hour). It is important that slippery areas be avoided in this test because immobilization caused by slipperiness yields invalid results.

4.1.3 Motion Resistance.

This test is repeated a sufficient number of times in test lanes of various soil strengths to produce an adequate motion resistance soil strength curve. The test vehicle should be in neutral gear, engine not running, and be towed at a speed of 3 to 5 kilometers/hour. A reasonably constant force should be measured for at least three vehicle lengths. In addition to tests conducted in soils, the motion resistance on a firm, level surface, such as a paved road, should be measured. The difference between firm surfaces and pull motion resistance is attributable to the soil.

4.1.4 Acceleration/Deceleration.

This test should be repeated at least five times on both hard and soft soils. Surface conditions must be uniform for each test, be free of obstacles, and virtually free of vegetation. The test area should be large enough to permit the vehicle to develop its top speed from a standing start and then coast or be braked to a stop.

4.1.5 Slope Negotiation.

a. The test should be negotiated on slopes on which the vehicle becomes immobilized. Slippery areas should be avoided because surface conditions strongly influence test results. Only the lowest gear of the test vehicle should be engaged for the test.

b. Maximum slope negotiation tests as described do not always follow the same pattern. Often measurements will apparently show the immobilization slope to be less steep than the negotiable slope. Moreover, one test may indicate that the vehicle can climb a certain slope and another test may indicate that an even steeper slope was climbed on softer soil. These anomalies are the result of small abrupt changes in the slope, surface roughness, pot holes, rocks or debris; or they could be the result of failure to measure soil strength properly. As a precautionary measure to aid in analyzing results, the attitude angle of the immobilized vehicle itself, i.e., the true slope it is attempting to climb should be measured because it may be steeper than the natural slope immediately adjacent. This is caused by rutting at the rear of a vehicle on a slope which is usually deeper than rutting at the front. The vehicle should not be allowed to spin its wheels or tracks for too long a time, or the attitude angle may reflect an erroneous slope.

c. An estimate of the maximum slope a vehicle can negotiate, for a given soil strength, may be obtained by referring to the appropriate maximum drawbar pull/slope soil strength curve, if one is available. Estimates for maximum slope negotiable can be obtained for conventional wheeled and tracked vehicles from the drawbar pull coefficient - RCI relations shown in Figure l. For example, a tracked vehicle with greater than 1.3 kilogram/cm^2 (4 pounds per square inch (psi)) ground pressure can, on an excess RCI of 20 (VCI +20), develop a drawbar of 54 percent of the vehicle weight or negotiate a maximum slope of 54 percent.

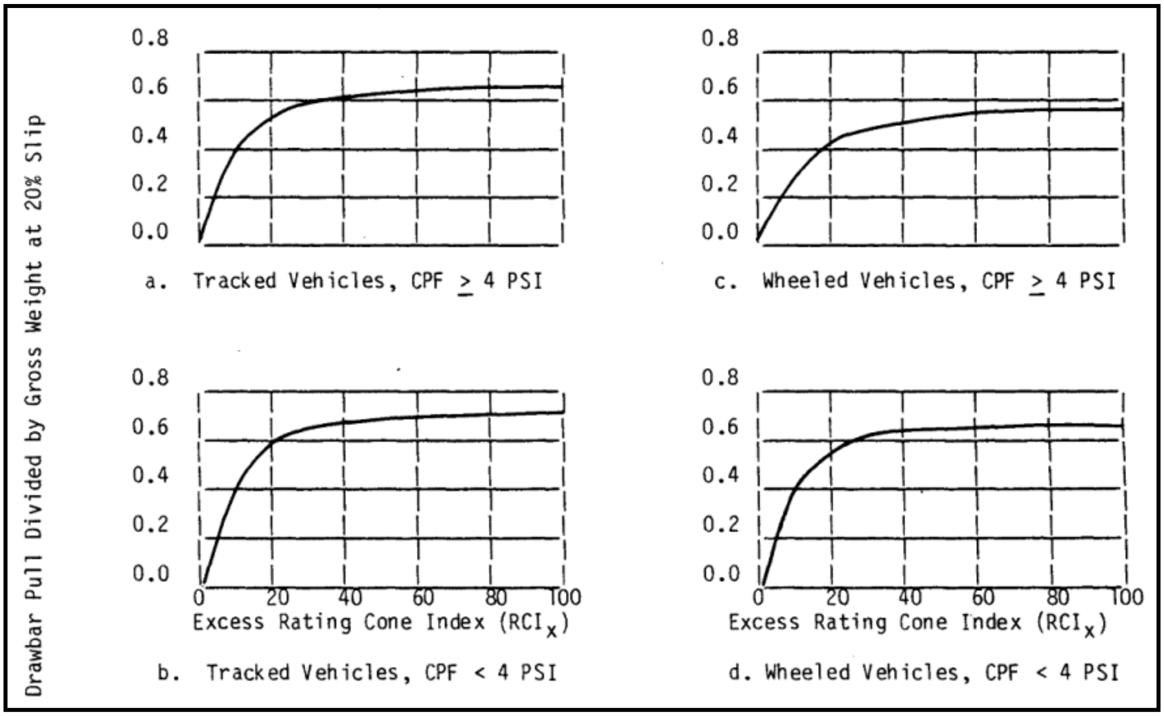

Figure 1. Drawbar pull-excess RCI curves for wheeled and tracked vehicles.

4.2 Vehicle/Vegetation Interaction Tests.

These tests should not be conducted during rains or for a period of six hours after rains have occurred. Several operators should be used in the tests to minimize individual driver influence on test results. In the single-tree failure and override tests, be sure that sufficient vegetation has been cleared from around the tree being failed to permit it to fall without becoming tangled in surrounding vegetation.

5. DATA REQUIRED.

5.1 One-Pass VCI.

a. Method. The driver engages the front differential (if applicable) and drives the vehicle through the test lane in the lowest gear at an extremely low speed of approximately 3 kilometers/hour (2 miles/hour). In the event of immobilization, the driver of the vehicle should be instructed not to attempt to move the vehicle by applying additional power, but to disengage the power train immediately and turn the ignition to the OFF position.

b. Data Required. Soil strength (CI and RCI) data are taken along both sides of the vehicle to determine the RCI at which it became immobilized. Other data documented in paragraph 3.4.1 should be recorded.

5.2 Drawbar Pull.

a. Method. A drawbar pull slip test is performed by attaching a load vehicle to the test vehicle through a cable and load cell, then determining pull in kilonewtons for a range of slips. If maximum drawbar pull only is required, then by trial and error find the maximum sustained load the test vehicle can pull in lowest gear while the traction element is travelling at a speed of 3 to 5 kilometers/hour (2 or 3 miles/hour). Pull is varied by changing the resistance offered from the load vehicle through braking it by increments, or by operating it in various gears (including reverse, in some cases) at different engine speeds. The exact process of finding the proper load will depend on the test vehicle, the load vehicle, the condition of the soil, and the skill of the vehicle operators. Some trial and error methods are necessary even for the best vehicle test operators. As in the case for VCI, it is important that the proper soil strength be associated with the test results, i.e., the maximum drawbar pull. It is also important that slippery areas be avoided, because immobilization caused by slipperiness yields invalid results. The collection of valid soil data is done most efficiently by first running the vehicle test, noting exactly the length of path in which the maximum drawbar pull occurred (wheels or tracks will be slipping at about 20 percent), and then measuring the required soil data in the immediate vicinity in locations undisturbed by the vehicle (not in the actual vehicle tracks). The actual number of tests is left to the judgment of the Test Officer, but there should be enough to sufficiently define the maximum drawbar pull-soil strength curve. The testing process may be simplified by the knowledge that the arctangent of the maximum slope attainable (slope negotiation), multiplied by the vehicle gross weight, is a close approximation of the maximum drawbar pull. Also, the one-pass VCI is the abscissa value at zero drawbar pull on a maximum drawbar pull-soil strength curve.

b. Data Required. The same type of soil measurements should be recorded as listed in paragraph 3.4.1 for the one-pass VCI test. The number of such measurements is left to the judgment of the Test Officer. A recommended policy is to record too many measurements rather than too few. About 20 sets of cone index readings and two to three remolding indexes should be sufficient. In addition, the following data should be collected for each test with a multichannel recorder: load cell measurements, distance vehicle travelled while sustaining maximum pull, and number of wheel revolutions for computation of slip. Table A-1 (in Appendix A) illustrates the data collection form to be used for soil data. The date, driver's name, vehicle type, and location should be noted on the multichannel recording.

5.3 Motion Resistance.

a. Method. The driver of the test vehicle should place the vehicle in all-wheel drive and shift the transmission into neutral. The vehicle is winched for a distance of 15 to 30 meters (50 to 100 feet) while recording the towing force on the load cell. This test should be repeated three or four times to determine an average motion resistance for a given soil strength.

b. Data Required. Soil measurements listed in paragraph 3.4.1 are required for areas adjacent to the vehicle tracks. Load cell measurements should be collected for each test.

5.4 Acceleration/Deceleration.

a. Method. The tests are conducted in 30 to 90 meter-long test lanes with uniform surface conditions. To obtain a wide range of surface conditions, several different test lanes should be laid out in terrain with level surface conditions. Two tests are conducted as follows:

(1) During the first test, the driver places the test vehicle in lowest gear and with full throttle begins a self-propelled, straight-line traverse of the test lane. For manual-transmission vehicles, from an initial standstill (zero speed) condition, the driver continues shifting gears (rapidly, as if drag racing) as he traverses the test lane until a predetermined point in the lane is reached; for automatic-transmission vehicles, the driver accelerates as quickly as possible in Drive mode. At this point, he rapidly disengages the power train and the vehicle is allowed to roll to a stop.

(2) During the second test, the same test lane is used; however, the vehicle is moved laterally one-half of the vehicle's width but the path is parallel to that used in the first test. The second test run is conducted in the same manner as the first, except instead of disengaging the power train and allowing the vehicles to roll to a stop when the predetermine point in the test lane is reached, brakes are applied and the vehicle is stopped per test requirement.

b. Data Required. For each test lane, soil parameters should be measured just outside the vehicle tracks, as outlined in paragraph 3.4.1. Continuous recordings should be made of the following, using the techniques indicated:

(1) Duration of Run - measured from time event markers on the oscillographic recorder.

(2) Total Distance Travelled - measured by means of a payout line.

(3) Revolution of Wheels - measured by means of the magnetic reed switch mounted on the drive shaft.

5.5 Slope Negotiation.

The soil data collection form in Table A-1 (Appendix A) should be used-to record soil data with all other data recorded on the multichannel recorder. The date, type of test, location, and name of driver should be noted on the recorder.

a. Method.

(1) This test is conducted by running the test vehicle up a slope in its lowest gear. If the vehicle is immobilized, the portion of the slope immediately behind the vehicle is considered to be negotiable and the steeper portion around the immobilization point is considered not negotiable. The maximum slope negotiable (the value of interest) is assumed to be half-way between the two portions.

(2) Tests with the definitive results described above do not always follow the same pattern. Often measurements will appear to show the immobilization slope to be less steep than the negotiable slope. Moreover, one test may indicate that the vehicle can climb a certain slope and another test may indicate that an even steeper slope was climbed on a softer soil. These anomalies are the result of small surface irregularities in the slope or failure to measure soil strength properly. As a precautionary measure to aid in analyzing results, the attitude angle of the immobilized vehicle itself, i.e., the true slope it is attempting to climb, should be measured because it may be steeper than the natural slope immediately adjacent.

b. Data Required. Soil data are collected to determine the soil type and soil strength (CI and RCI) in areas adjacent to the immobilized test vehicle. The attitude angle of the vehicle is measured by means of pre-establishing two reference points on the test vehicle, so that a line drawn through them when the vehicle is on level ground will also be level. Therefore, the angle between the horizontal and the line through the two reference points while the vehicle is immobilized is the attitude angle. Table A-2 (Appendix A) illustrates a data collection form for use with slope tests.

5.6 Discrete Obstacle.

a. Method. Each obstacle is challenged by the test vehicle at approximately 3 kilometers/hour (2 miles/hour) at the driver's discretion.

b. Data Required. If an immobilization occurs, the nature of the immobilization is described, e.g., bumper drag or approach angle too steep. In addition, a profile should be made of the obstacle encountered, as described in paragraph 3.4.6.

5.7 Single-Tree Override.

a. Method. This test is conducted in two parts:

(1) Single-Tree Failure. The cable from the winching vehicle is connected to the front bumper of the test vehicle through a V-shaped arrangement that permits an even pull on both shackles of the front bumper without interfering with the failure of the tree. The test vehicle is placed in a position so that its front bumper is against the tree. The driver of the test vehicle places the vehicle in all-wheel drive and puts the transmission in neutral. The test vehicle is then winched until the tree fails because of root or stem failure, or until the tree is pushed down by bending. At this point the tree is considered failed and the winching action is stopped. During the winching action, continuous recordings of forces exerted through the load cell are made.

(2) Single-Tree Override. This second part commences after marking the end of the first part on the recording. The winching action is initiated again, and recordings are made of the forces being exterted through the winch cable until the test vehicle has cleared the branches of the failed tree.

NOTE: When a tree fails, it may fall on the winching cable and cause non-related forces to be measured erroneously while the operator is trying to winch the test vehicle across the failed tree.

If possible, the cable should be removed from the test vehicle and re-routed through the branches to prevent measuring the force required to pull the cable through the branches.

b. Data Required.

(1) In addition to the data listed in paragraph 3.4.7, the following should be recorded for each challenged tree:

(a) Continuous force measurements during winching action.

(b) Species of tree.

(c) Mode of tree failure (stem breaking, stem bending without breaking, root failure, uprooting, etc.).

(d) Abnormal vehicle configurations (root structure of tree caught under carriage, wheel(s) off the ground, vehicle damage, etc.).

(2) Table A-3 (Appendix A) shows a data collection form suitable for use in conduct of the single-tree override test.

5.8 Multiple-Tree Override.

a. Method. The positioning and winching of the test vehicle in this test are the same as described for single-tree override. Test sites used in this phase of testing are selected with tree sizes appropriate to the vehicle being tested, as determined by single-tree failure results. The primary difference between the single and multiple tree tests is that, in multiple tree tests failing of any one tree is complicated by interference of crown entanglement and vines of neighboring trees.

b. Data Required. In addition to the data prescribed in paragraph 5.7.2, the relative spacing of the stems of all trees being overridden must be recorded.

5.9 Grassland Override.

a. Method. The test vehicle is winched through an undisturbed grass area while force measurements are recorded through the load cell and load cell amplifier. At the end of the path, the vehicle is returned to the starting point and again winched through the same path with the grass cleared by cutting if necessary. Forces are recorded again and the difference of forces is the force required to override the grass.

b. Data Required. In addition to the data shown in paragraph 3.4.9, the forces required for the vehicle to penetrate the grassland are recorded. Table A-1 (Appendix A) illustrates the data collection form to be used for soils. Stem density, type of vehicle, location, date, and name of driver should be noted on the recording.

6. PRESENTATION OF DATA.

6.1 One-Pass VCI.

a. Data to determine the CI must include test results of both "go" or "no-go" conditions associated with a rating cone index for fine-grained soils and sands with fines poorly drained, or cone index for clean sands. If a vehicle becomes immobilized, only soil strength data measured along the vehicle path in undisturbed soil in the immediate vicinity of immobilization should be averaged and associated with "no-go" conditions. In the case of a "go" along a test course which is obviously stronger in, for example, one-half the course than the other, the data analyst will determine the strength that represents the weaker end and associate that strength with the "go" test.

b. After the RCI has been determined (Table A-1), a plot is made of the RCI values obtained for the "go" and "no-go" tests along a horizontal line (no ordinate is required) as shown in Figure 2. As in Figure 2, an absolute value of VCI could be determined experimentally if a sufficient number of "go", "no-go" tests were conducted near the VCI. From a practical viewpoint, however, the Test Officer is restricted in the range of soils strength values that he can locate within the test areas available to him. He must attempt to locate test lanes with a continuous range of soils strengths near the expected VCI.

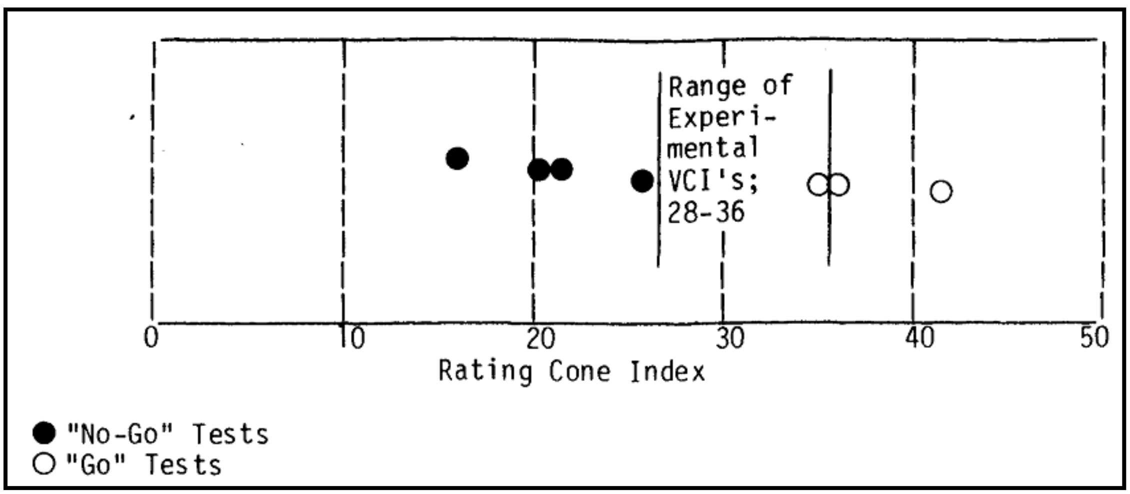

Figure 2. Example of graphic determination of experimental VCI.

6.2 Drawbar Pull.

a. This series of tests is conducted to define a maximum drawbar pull-soil strength curve. The drawbar coefficient is a very close approximation of the tangent of the maximum angle that the vehicle can negotiate in the same soil conditions. The testing process may be aided by the knowledge that a curve of maximum drawbar pull/weight, or maximum slope versus soil strength plotted in terms of excess RCI goes through the origin and assumes a characteristic shape as in

Figure 1. Contact Pressure Factor (CPF) is computed for tracked vehicles by dividing gross vehicle weight by the area of tracks in contact with the ground. CPF for wheeled vehicles is computed according to the following formula:

$$\text{CPF} = \frac{\text{gross vehicle weight (pounds)}}{[\text{nominal tire width, inches}] \text{ x } \left[\dfrac{\text{outside diameter of tire, inches}}{2}\right] \text{ x } [\text{number of tires}]}$$

b. If the curve developed by tests deviates significantly from the pertinent curve in this reference (Figure 1), the test curve is possibly in error and the Test Officer should reevaluate the procedures being used.

6.3 Motion Resistance-Soil Strength.

Data collected present a continuous record of the force required to tow the vehicle. These forces should be averaged and then plotted against soil strength to produce a motion resistance-soil strength curve.

6.4 Acceleration/Deceleration.

a. To analyze the data obtained in this test, the time-distance recordings must be examined. A portion of a typical recording is shown in Figure 3.

NOTE: When the test vehicle is moved into position on the test lane for the start of a test run, it is moved forward a foot or so to a position such that when the vehicle starts to move the channel (CH)1 (distance) and CH 2 (drive-shaft revolution) event markers activate and mark the position on the oscillographic recording. In order to accomplish this, the switches for CH1 and CH2 must be synchronized. If this is not done, important information regarding maximum acceleration may be lost.

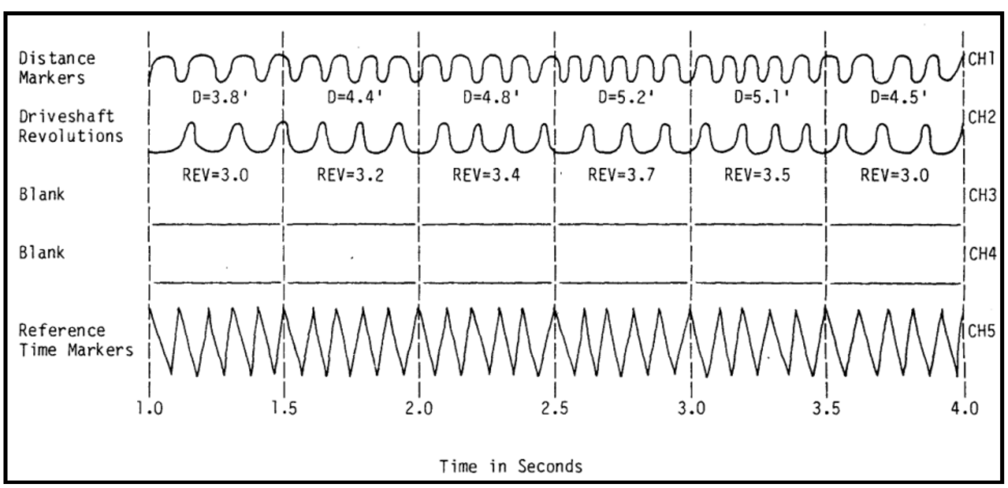

Figure 3. Portion of typical time-distance recording obtained in Acceleration/Deceleration Tests for M715, 5/4-ton truck.

b. For illustrative purposes, the portion of the recording shown in Figure 3, represents the time when the test vehicle reached maximum velocity and then began to roll to a stop (decelerate). The recording shown in Figure 3 is analyzed in the following manner:

(1) Knowing the frequency of the reference time markers, the chart can be subdivided into time intervals as indicated on the bottom of the chart. For the major portion of the recording used for illustrative purposes (the time when the test vehicle reached maximum velocity and then began to roll to a stop), analysis of the recording at time intervals of once each 1/2 second is normally sufficient. In the earlier portions of the first (0 to 1.5 seconds), however, analysis of the recording should be conducted every 0.1 second to ensure that a proper value for maximum acceleration can be derived. The maximum acceleration of the vehicle invariably occurs during this early phase of the test.

(2) A vertical line is then drawn on the chart to facilitate computation of distance traveled and speed of wheel revolutions per time interval. Having previously instrumented the vehicle in order that one event marker per foot (0.3 meter) of travel would be obtained, CH1 can be analyzed for distance by merely counting the number of event markers in a given time interval, as shown in Figure 3 where “D” equals distance.

(3) Next, the speed of revolution of the driveshaft is considered. This is extremely important because these data show how far the vehicle should have moved during each time interval, and hence the amount of slip of the drive wheels or tracks. If the slip exceeds 20 percent, the test results obtained are questionable.

(4) Using the above data, velocity can be computed for the various time intervals using the following equation:

$$V = \frac{\Delta D}{\Delta t}$$

where: V = Vehicle velocity
ΔD = Distance vehicle moved during the time interval Δt
Δt = Time interval selected

(5) For illustrative purposes, the time interval between 3.0 and 3.5 seconds is chosen from Figure 3, and vehicle velocity is computed as follows:

$$V = \frac{\Delta D}{\Delta t} = \frac{5.1\text{ft}}{0.5\text{s}} = 10.2\,\frac{\text{ft}}{\text{s}}$$

(6) In order to check the reliability of the acceleration data, percent slip of the wheels is computed as follows:

$$\text{Percent Slip} = \frac{\text{Distance Wheels Moved} - \text{Distance Vehicle Moved}}{\text{Distance Wheels Moved}} \text{ x } 100$$

NOTE: Distance vehicle moved is determined from the payout line.

(7) Where the distance the wheels moved is the number of revolutions of the driveshaft times the distance the wheel moves for each revolution of the driveshaft. Distance wheels moves for each revolution of the driveshaft can be determined experimentally by driving the vehicle on a hard surface and noting the distance the wheel moves for each event marker on CH2.

(8) After all recordings have been analyzed in the above manner, acceleration/deceleration curves can be plotted for this example as shown in Figure 4. From this type of curve the maximum acceleration and average deceleration can be computed.

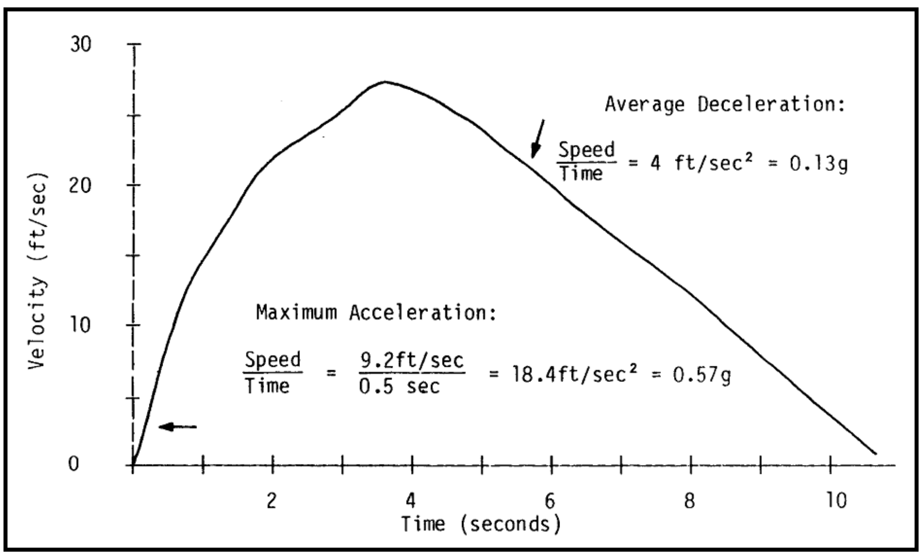

Figure 4. Typical acceleration/deceleration curve.

(9) The analysis of the second phase of the acceleration/deceleration test yields the braking coefficient of the test vehicle. The average deceleration in this phase equals the braking coefficient and is computed in the same manner as is the average deceleration of the first phase.

6.5 Slope Negotiation.

The analysis necessary for these tests consists of plotting the slope negotiating capabilities of the various test vehicles on a "go" or "no-go" basis for various soil types and strengths. A point to remember is that for a given soil type (fine or coarse-grained soil) and strength, the maximum

drawbar pull coefficient closely approximates the tangent of the maximum slope that the vehicle can negotiate.

6.6 Discrete Obstacle.

a. The analysis of the obstacle crossing data consists of noting whether the test was in a "go" or "no-go" condition and estimating the principle cause, e.g., slope, geometric interference, and soil strength.

b. Knowledge of the size, shape, and kind of obstacle that a vehicle can and cannot surmount or which slows it down is required in estimating effects of discrete obstacles on vehicle mobility.

6.7 Single-Tree Override.

a. This test is designed to measure the maximum force required to fail and override a tree; with the maximum failure force nearly always occurring just prior to tree failure (as the stem breaks or bends, or as the tree is up-rooted or its root structure is broken). The maximum override force may occur during any portion of the recording. These forces are plotted against tree stem diameters in the tree failure portion of the test (Figure 5). The override forces can also be plotted against tree stem diameter as shown in Figure 6.

b. Two things should be highlighted in a plot of failure force versus stem diameter: the tractive force and the motion resistance force.

(1) The tractive force represents the maximum force the test vehicle is capable of applying against a tree, and for this type of test should be presented on the plot as an upper limit of vehicular performance. This is crucial in considering that the tractive force may have been exceeded through the winching action of pulling the test vehicle across the challenged tree, and without this maximum capability represented on the plot, the operator may exceed the strength of the leading edge of the vehicle.

(2) The second highlight is the motion resistance. This is the force required to overcome the inherent resistance of the vehicle towards movement, and represents the force required to fail a tree of zero stem diameter on a stem diameter versus failure force curve. Hence, the plotted curve should intersect the force-axis at the motion resistance force value. The curve will probably have the form:

$$\text{Force} = \text{Motion Resistance} + \text{a}(\text{Stem Diameter})^{\text{b}}$$

where “a” and “b” are empirical constants to be solved through appropriate field tests and a mathematical curve fitting routine.

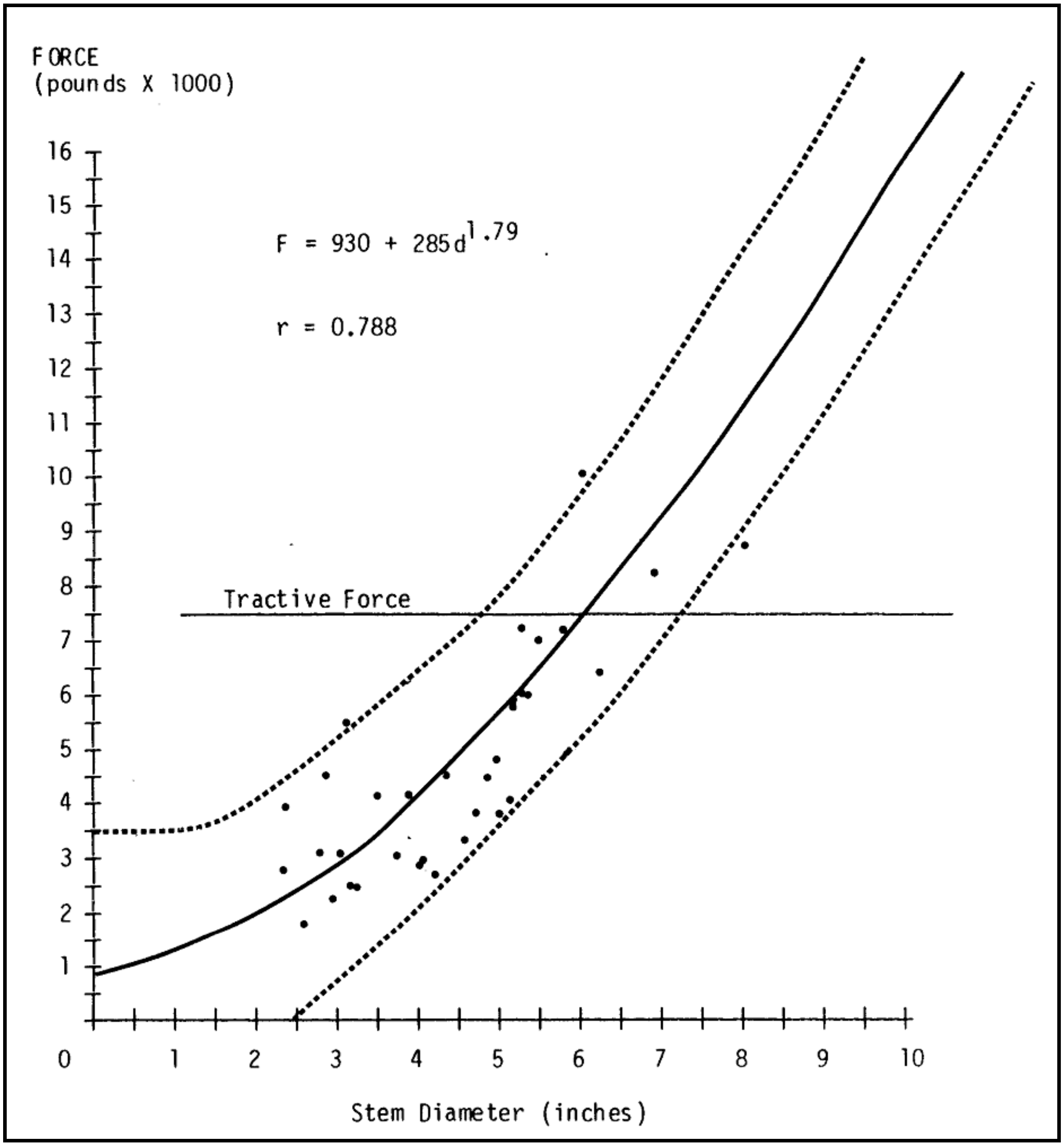

Figure 5. Force required to fail a tree with M715, 5/4-ton truck.

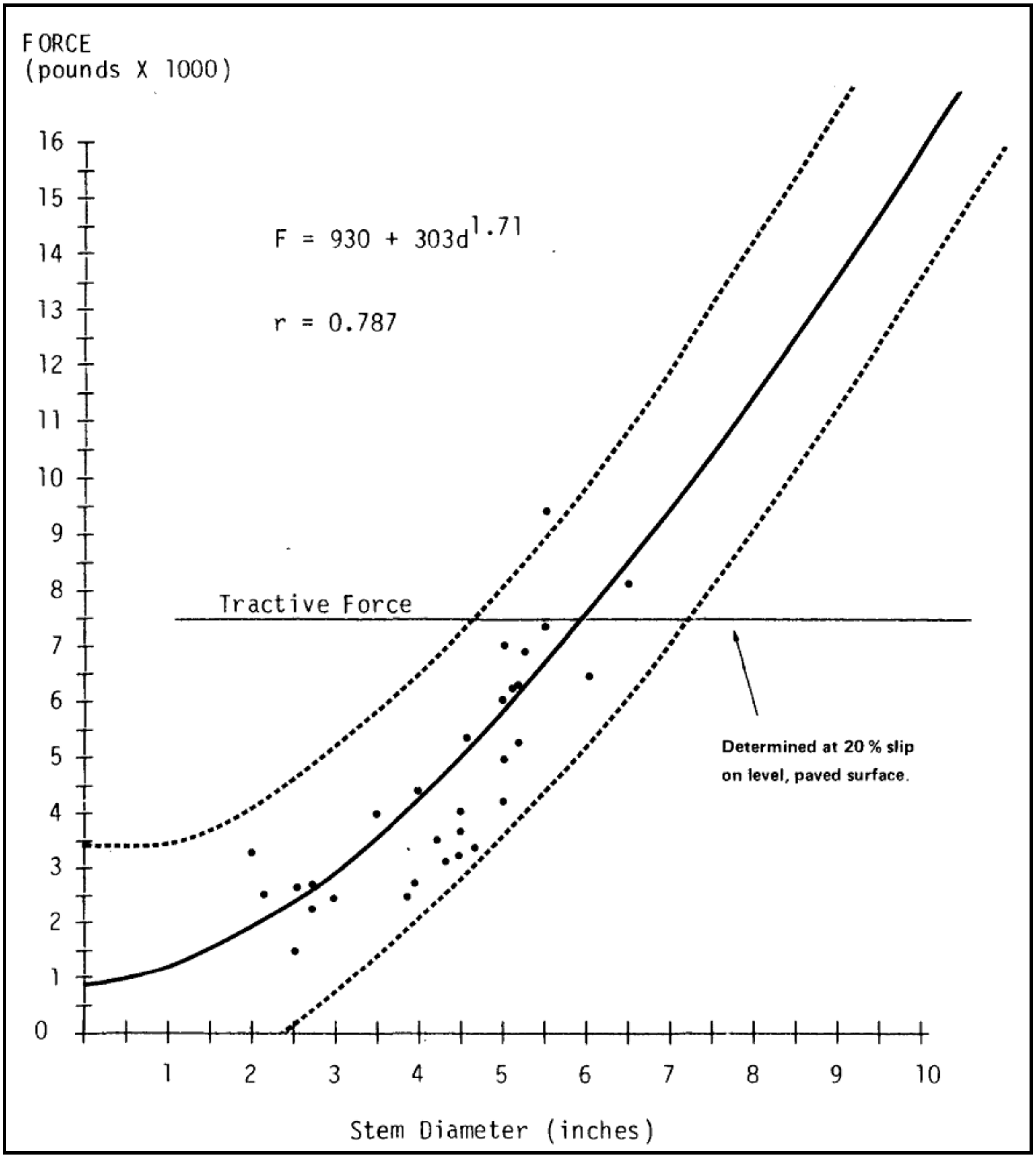

Figure 6. Force required to fail and override a tree with M715, 5/4-ton truck.

6.8 Multiple-Tree Override.

The data gathered in this test differ from the single-tree test in that the forces to fail and override cannot be separated. This occurs because while one tree is being failed another is being

overridden. However, close observation of the recordings will reveal peak forces occurring at intervals that are dependent upon the spacing of the trees being overridden. The procedure for data analysis matches each force to the tree which was overridden and then uses the average force, which will correspond to an average tree diameter, to plot this against the single tree predicted force for the same size tree (obtained from the curve of force-to-fail vs. single-tree stem diameter). After a series of single-tree vs. multiple-tree forces have been plotted (obtained from several multiple tree tests), a curve can be fitted to the data pairs to obtain a relation between single-tree and multiple-tree failure override force. Previous tests have shown that this relationship is linear (Figure 7).

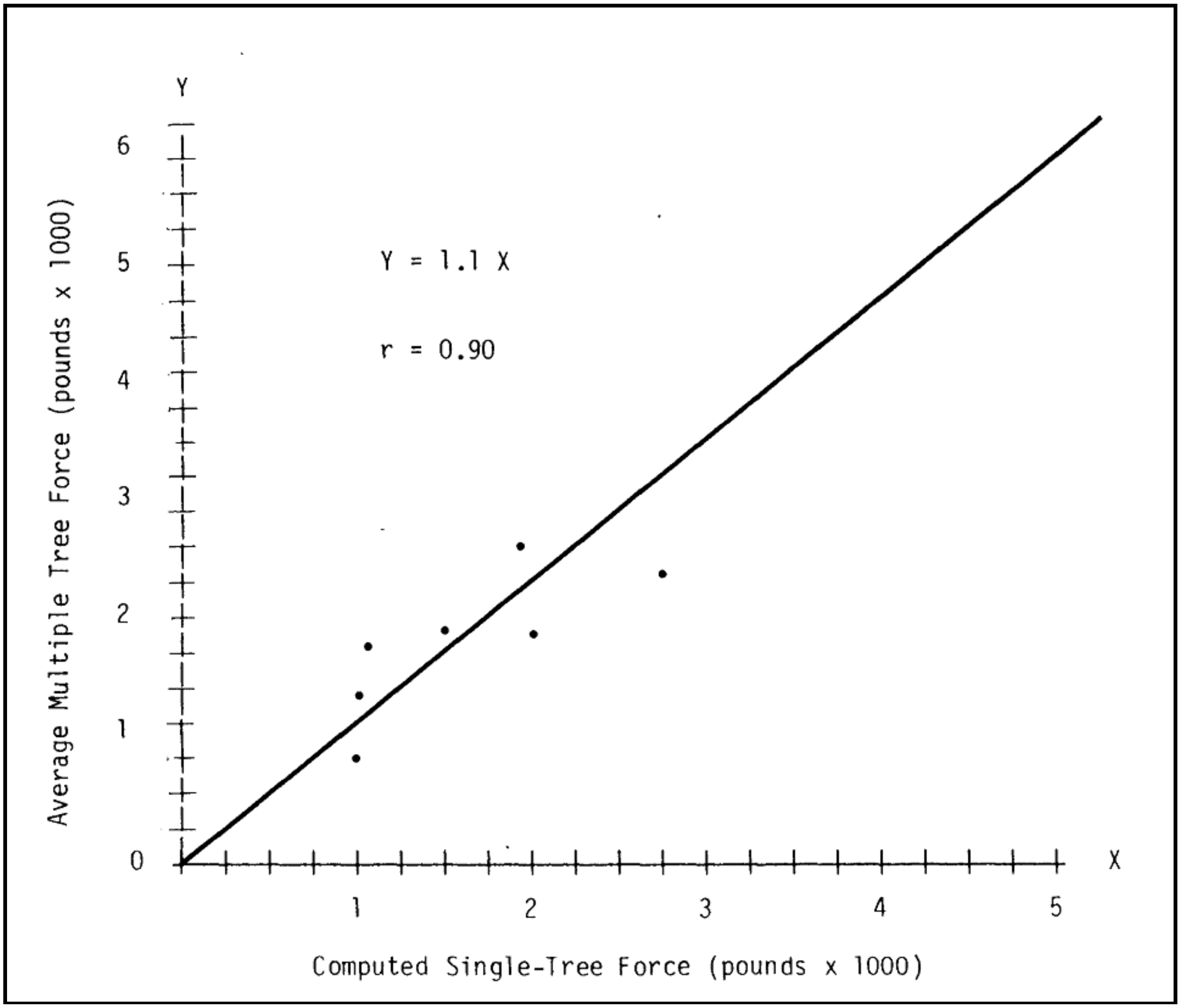

Figure 7. Single-tree vs. multiple-tree force required to override.

6.9 Grassland Override.

Data gathered during this test indicate the averaged force measured while grass is overridden on the first and second passes. These data are then presented in tabular form (when more than one type of vehicle is used for the test) showing both averages and the percent increase in force caused by the override on the first pass.

APPENDIX A. DATA COLLECTION FORMS.

TABLE A-1. SOIL DATA FORM

Type Test: ____________________ Date: ________________ Location: ______________________________

1. USCS Soil Type Classification:	0- to 6-Inch Depth Sample 1	6- to 12-Inch Depth Sample 1
Can Number		
Soil Type		

2. Soil Moisture Content

Depth (inches)	Can Number		Moisture Content (%)		Dry Density (lbs/ft^3)	
	Sample 1	Sample 2	Sample 1	Sample 2	Sample 1	Sample 2
0-1						
1-6						
6-12						

3. Remolding Index (RI):

	Cone Index (CI)		Rating Cone Index (RCI)
Depth (inches)	Before 100 blows	After 100 blows	
0			
2			
4			
6			
8			
10			
12			
RI			

$$RI = \frac{\sum Cone\ Index\ after\ remolding}{\sum Cone\ Index\ before\ remolding}$$

$$RCI = RI\ x\ CI$$

APPENDIX A. DATA COLLECTION FORMS.

TABLE A-1. CONTINUED

4. Cone Index Before Traffic

		Distance Along Test Lane (feet)									
Depth (inches)	Rut	0	10	20	30	40	50	60	70	80	90
0	Right										
	Left										
2	Right										
	Left										
4	Right										
	Left										
6	Right										
	Left										
8	Right										
	Left										
10	Right										
	Left										
12	Right										
	Left										
Total											
Average											

5. Vehicle weight configuration: ______________________________

6. Tire Pressure: ______________________________

____

7. Rut depth when vehicle immobilization occurred (inches): ______________

8. Section of test lane in which immobilization occurred: ______________

9. Identification of test vehicle: ______________________________

10. Driver’s name: ______________________________

NOTE: This data form can be used for other soil-vehicle test.

APPENDIX A. DATA COLLECTION FORMS.

TABLE A-2. SLOPE DATA FORM

Test Vehicle: ______________ Date: __________ Location: ________________

Driver: ____

1. Soil data at point where vehicle immobilization occurred (see table A-1): ______________

____

2. Slope (%) on course where vehicle immobilization occurred: ______________

3. Vertical distance (inches) from vehicle CG to ground (h): ______________

4. Distance (inches) from CG to point perpendicularly beneath center of rear axle (d): __________

____

5. Description of the terrain along test lane: ______________________

____

____

____

____

____

APPENDIX A. DATA COLLECTION FORMS.

TABLE A-3. TREE FAILURE AND OVERRIDE DATA FORM

Test Vehicle: ____________________ Date: ____________ Location: ________________________

Driver: ____

1. Vegetation Data
   a. Stem diameter at breast height (DBH) (inches) ____________________
   b. Vegetation type ____________________
   c. Mode of tree failure ____________________

2. Vehicle Characteristics
   a. Identification ____________________
   b. Test weight ____________________
   c. Bumper height (inches) ____________________
   d. Ground clearance (inches) ____________________

3. Force Data
   a. Force required to fail tree (lb) ____________________
   b. Force required to override tree (lb) ____________________

4. USCS Soil Type Classification

	Depth of Sample (inches)	
	0-6	6-12
a. Can Number		
b. Soil Type (USCS)		

5. Soil Moisture Content (%)

	Depth of Sample (inches)	
	0-6	6-12
a. Can Number		
b. Moisture Content (%)		

APPENDIX A. DATA COLLECTION FORMS.

TABLE A-3. CONTINUED

6. Cone Index

CONE INDEX		
Depth (inches)	Sample 1	Sample 2
0		
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
12		
18		
Average 0-6		
Average 6-12		
Average 12-18		

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APPENDIX B. COMPUTATION OF VEHICLE CONE INDEX.

1. To compute VCIs for fine-grained soil, a mobility index (MI)* is computed as follows:

<u>Self-Propelled All-Wheeled-Drive Vehicles</u>:

$$\text{Mobility Index} = \left(\frac{\text{contact pressure factor} \times \text{weight factor}}{\text{tire factor} \times \text{grouser factor}} + \text{wheel load factor} - \text{clearance factor} \right) \times \text{engine factor} \times \text{transmission factor}$$

where

(1) Contact pressure factor $= \dfrac{\text{gross weight, lb}}{\text{nom. tire width, in.} \times \dfrac{\text{outside diam of tire, in.}}{2} \times \text{No. of tires}}$

(2)

Gross weight, lb	Weight Factor
<2,000	Y = 0.555X
2,000 to 13,500	Y = 0.033X + 1.050
13,501 to 20,000	Y = 0.142X – 0.420
20,000	Y = 0.278X – 3.115

where
Y = weight factor
$X = \dfrac{\text{gross weight, kips**}}{\text{number of axles}}$

(3) Tire factor $= \dfrac{10 + \text{tire width, in.}}{100}$

(4) Grouser factor: With chains = 1.05
Without chains = 1.00

(5) Wheel load factor $= \dfrac{\text{gross weight, kips**}}{\text{number of axles} \times 2}$

(6) Clearance factor $= \dfrac{\text{clearance, in.}}{10}$

(7) Engine factor: ≥10 hp/ton = 1.00
<10 hp/ton = 1.05

(8) Transmission factor: Automatic = 1.00
Manual = 1.05

** 1 kips = 1000 pound

APPENDIX B. COMPUTATION OF VEHICLE CONE INDEX.

Self-Propelled Tracked Vehicles:

$$\text{Mobility Index} = \left(\frac{\text{contact pressure factor} \times \text{weight factor}}{\text{track factor} \times \text{grouser factor}} + \text{bogie factor} - \text{clearance factor} \right) \times \text{engine factor} \times \text{transmission factor}$$

where

(1) Contact pressure factor = $\dfrac{\text{gross weight, lb}}{\text{areas of tracks in contact with ground, sq in.}}$

(2) Weight factor:

Less than 50,000 lb = 1.0
50,000 to 69,999 lb = 1.2
70,000 to 99,999 lb = 1.4
100,000 lb or greater = 1.8

(3) Track factor = $\dfrac{\text{Track width, in.}}{100}$

(4) Grouser factor:

Grousers less than 1.5 in high = 1.0
Grousers more than 1.5 in high = 1.1

(5) Bogie factor = $\dfrac{\text{gross weight, lb, divided by 10}}{\left(\text{total number of bogies on tracks in contact with ground}\right) \times \left(\text{area, sq in., of 1 track shoe}\right)}$

(6) Clearance factor = $\dfrac{\text{clearance, in.}}{10}$

(7) Engine factor:

≥10 hp/ton of vehicle wt = 1.00
<10 hp/ ton of vehicle wt = 1.05

(8) Transmission factor: Automatic = 1.00; manual = 1.05

APPENDIX B. COMPUTATION OF VEHICLE CONE INDEX.

2. After computing of the mobility index, VCIs are obtained using the following equations:

Self-Propelled All-Wheeled-Drive Vehicles:

(1) One-Pass VCI $$VCI_1 = 11.48 + 0.2\ MI - \left(\frac{39.2}{MI + 3.74}\right)$$

(2) Fifty-Pass VCI $$VCI_{50} = 28.23 + 0.43\ MI - \left(\frac{92.67}{MI + 3.67}\right)$$

Self-Propelled Tracked Vehicles:

(1) One-Pass VCI $$VCI_1 = 7.0 + 0.2\ MI - \left(\frac{39.2}{MI + 5.6}\right)$$

(2) Fifty-Pass VCI $$VCI_{50} = 19.27 + 0.43\ MI - \left(\frac{125.79}{MI + 7.08}\right)$$

3. A typical example resulting from using the above equations is as follows:

Mobility Index and VCI for M715 1¼-Ton Truck

Computation of Mobility Index:

(1) Contact pressure factor $= \dfrac{8000}{9 \times \frac{34}{2} \times 4} = 13.07$

(2) Weight factor: $0.033 \times 4 + 1.050 = 1.18$

(3) Track factor = $\dfrac{10 + 9}{100} = 0.19$

(4) Grouser factor: $= 1.00$

(5) Wheel load factor = $\dfrac{8}{2 \times 2} = 2.00$

(6) Clearance factor = $\dfrac{10}{10} = 1.00$

(7) Engine factor: $= 1.00$

(8) Transmission factor: $= 1.05$

$$\text{Mobility Index} = \left(\frac{13.07 \times 1.18}{0.19 \times 1.00}\right) + 2.0 - 1.0 \times 1.0 \times 1.05 = 13.07$$

APPENDIX B. COMPUTATION OF VEHICLE CONE INDEX.

Computation of VCI:

(1) $VCI_1 = 11.48 + (0.2 \times 86.26) - \left(\frac{39.2}{86.26 + 3.74}\right) = 28$

(2) $VCI_{50}\ \ 28.23 + (0.43 \times 86.26) - \left(\frac{92.67}{86.26 + 3.67}\right) = 64$

APPENDIX C. TEST SITE PARAMETERS.

Afobaka, Suriname

This test area, located in the Brokopondo district, is on the west shore of the Suriname River, 2 kilometers north of the Afobaka Dam, and 96 kilometers south of Suriname's capital city, Paramaribo.

The test site consists of a 30-kilometer track running through tropical forest. The track is a combination of a bauxite/dirt base with grades on the road up to 20 percent and log bridges crossing 11 creeks. The track site is located in a private concession used mainly for gold mining; however, logging operations are active in the area. The track is set up as a 30-kilometer loop allowing vehicles to conduct continuous round-trip test cycles. Figure C-1 shows one of the jungle trails available for cross-country mobility testing. Figures C-2 through C-25 provides information on various test sites.

Figure C-1. Jungle trail at Afobaka Test Site.

APPENDIX C. TEST SITE PARAMETERS.

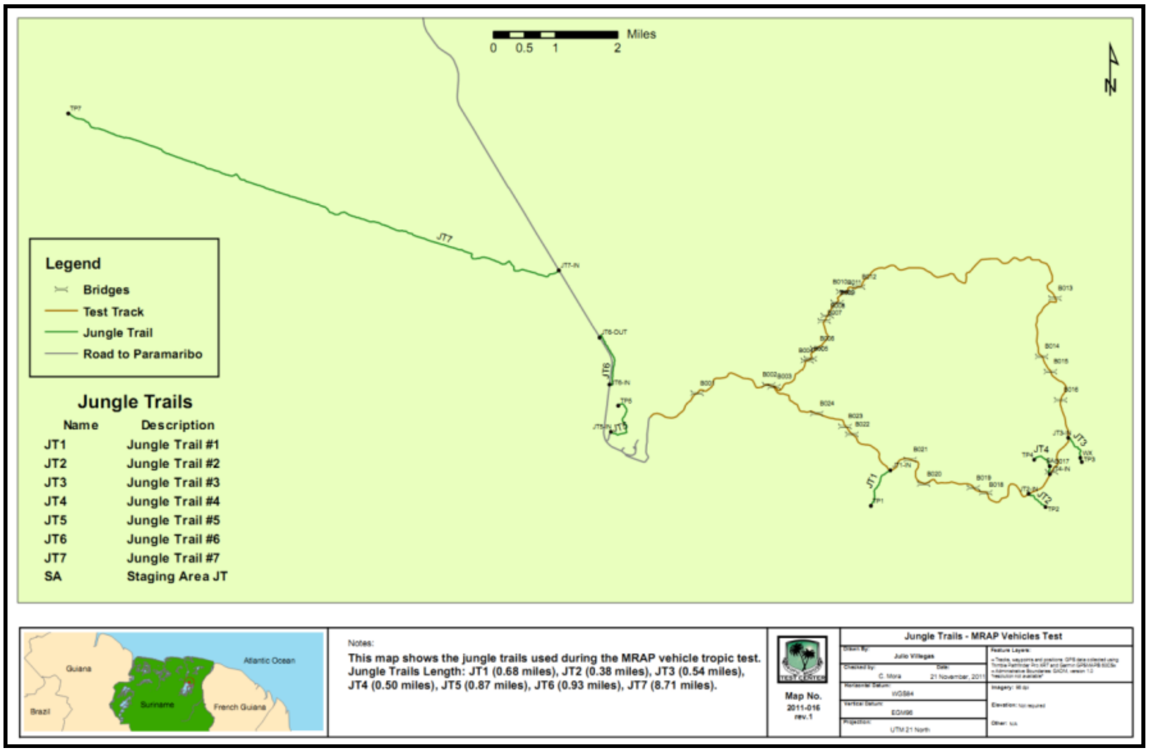


Figure C-2. Thirty-kilometer test track and jungle trails at Afobaka Test Site.

Figure C-3. Test track at Afobaka Test Site.

APPENDIX C. TEST SITE PARAMETERS.

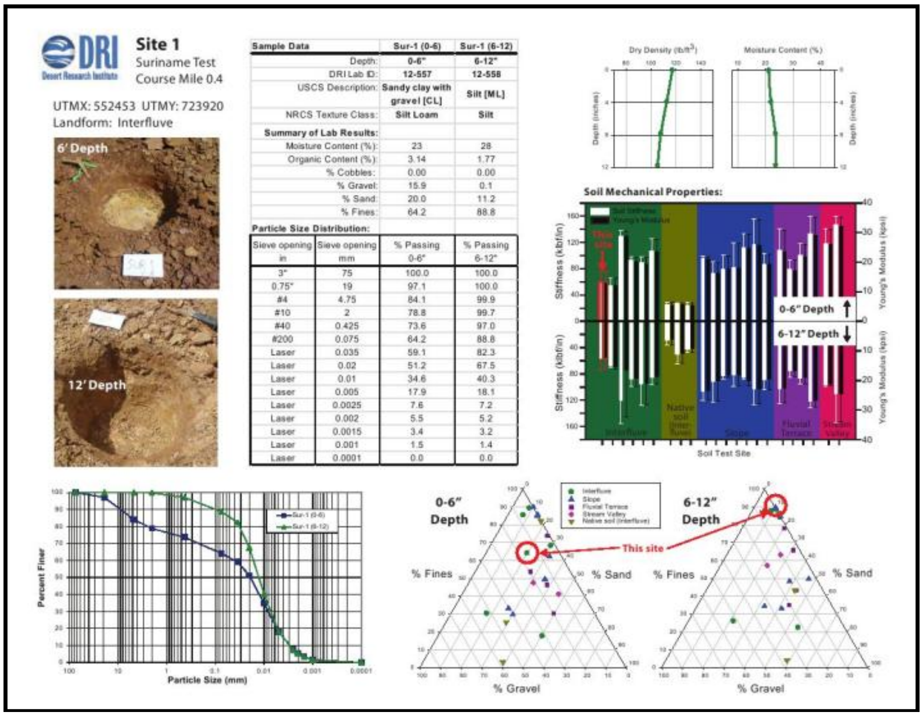


Figure C-4. Soil classification charts by Desert Research Institute Site 1 at Afobaka Test Site.

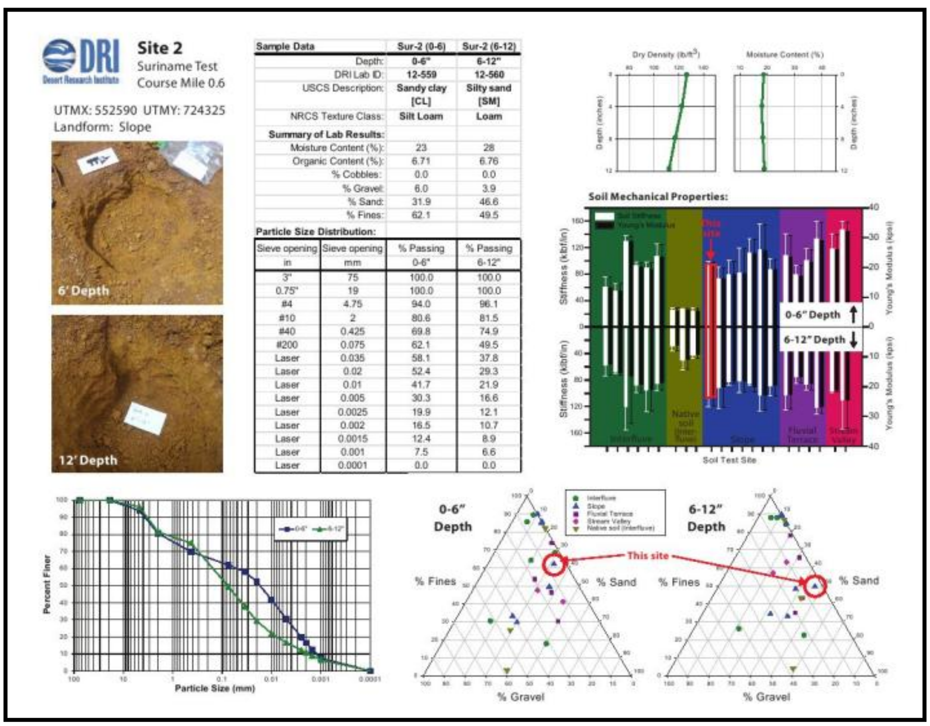


Figure C-5. Soil classification charts by Desert Research Institute Site 2 at Afobaka Test Site.

APPENDIX C. TEST SITE PARAMETERS.

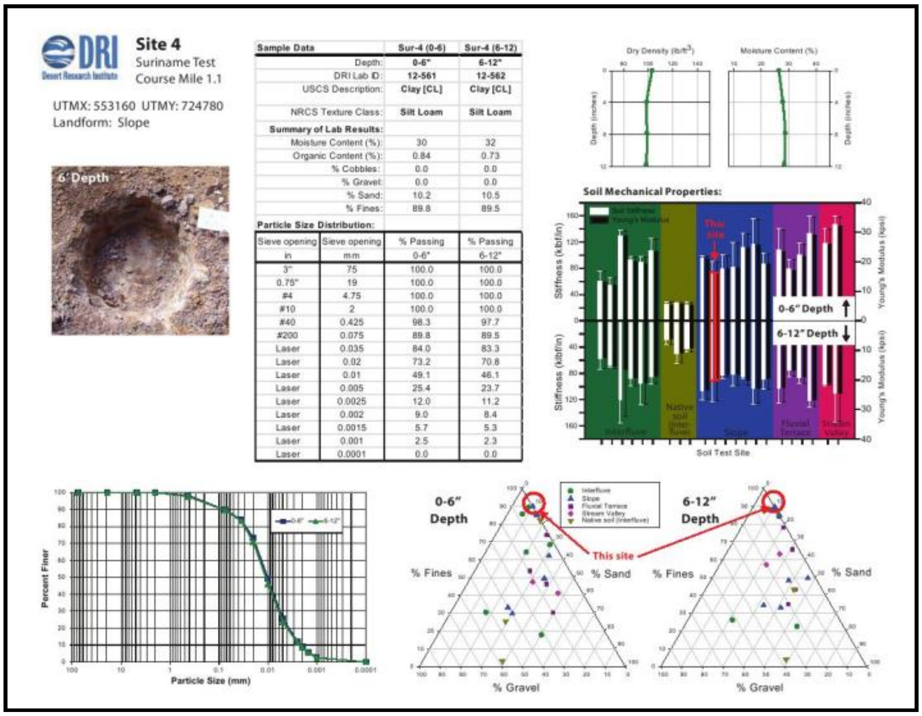


Figure C-6. Soil classification charts by Desert Research Institute Site 4 at Afobaka Test Site.

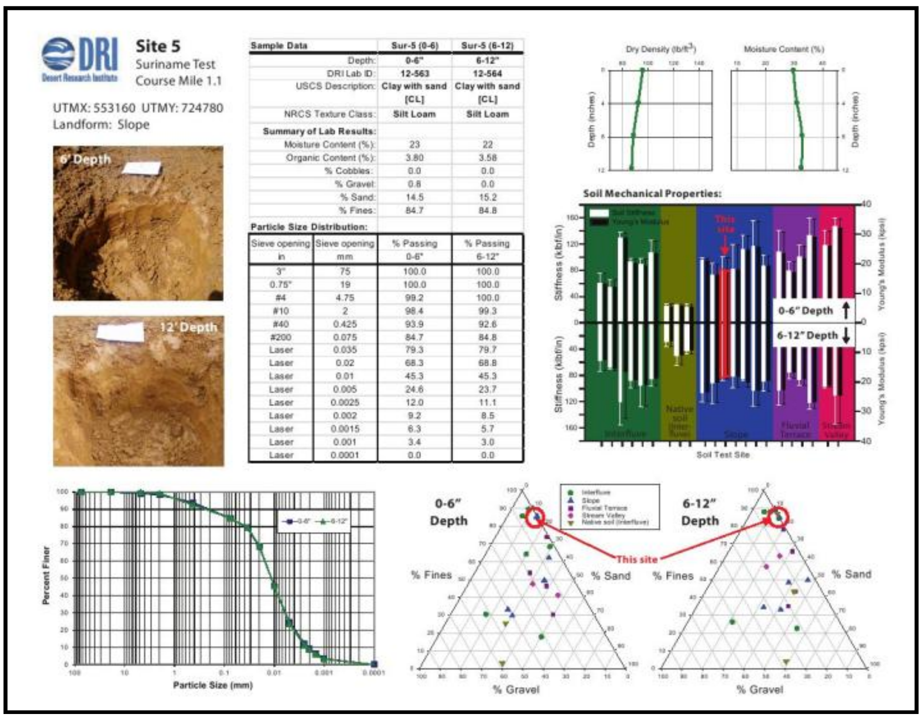


Figure C-7. Soil classification charts by Desert Research Institute Site 5 at Afobaka Test Site.

APPENDIX C. TEST SITE PARAMETERS.

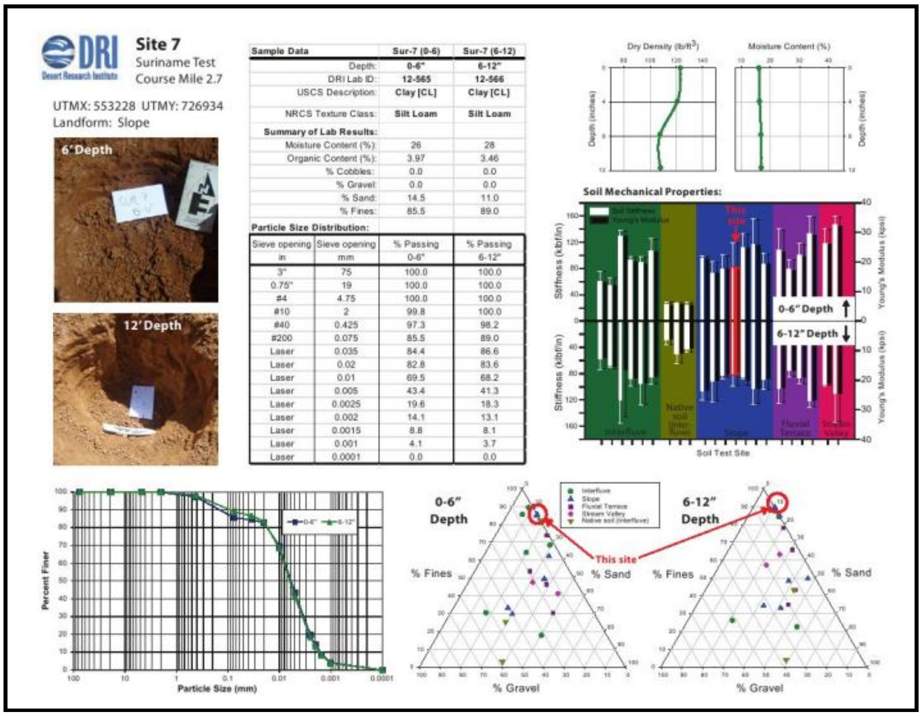


Figure C-8. Soil classification charts by Desert Research Institute Site 7 at Afobaka Test Site.

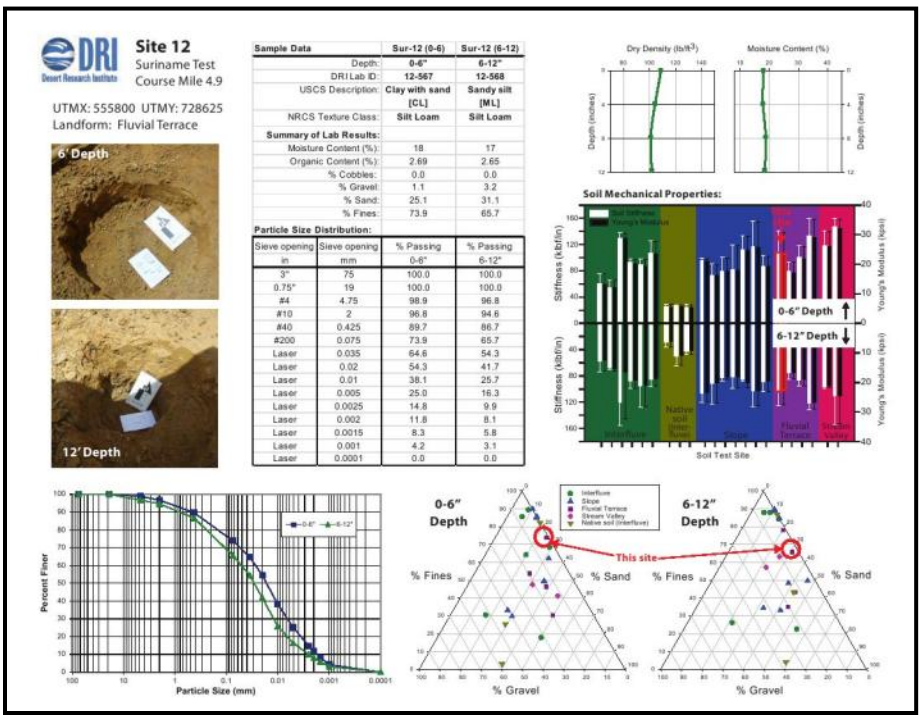


Figure C-9. Soil classification charts by Desert Research Institute Site 12 at Afobaka Test Site.

APPENDIX C. TEST SITE PARAMETERS.

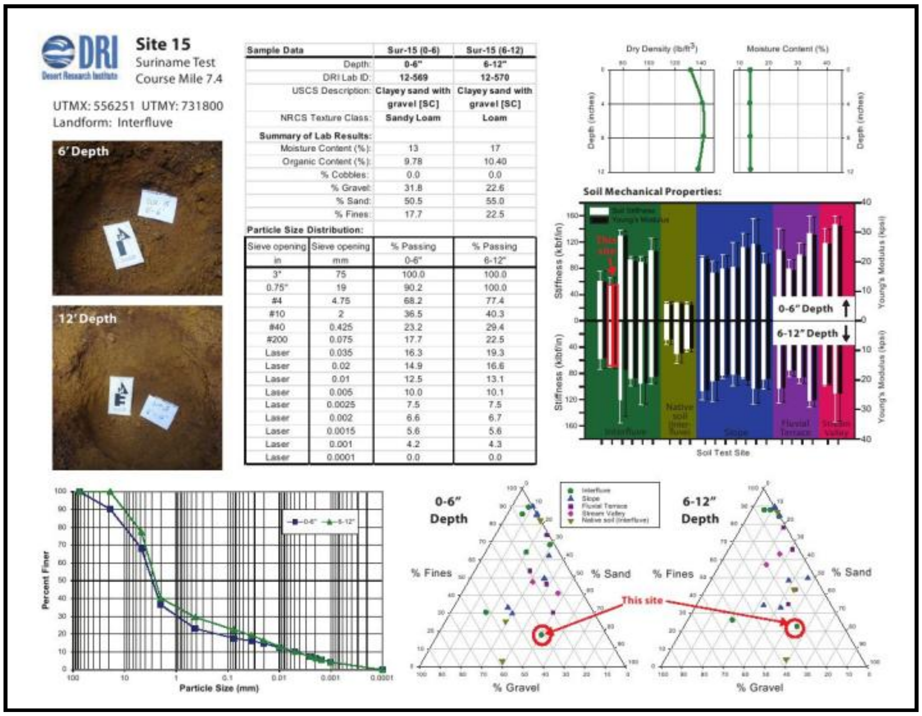


Figure C-10. Soil classification charts by Desert Research Institute Site 15 at Afobaka Test Site.

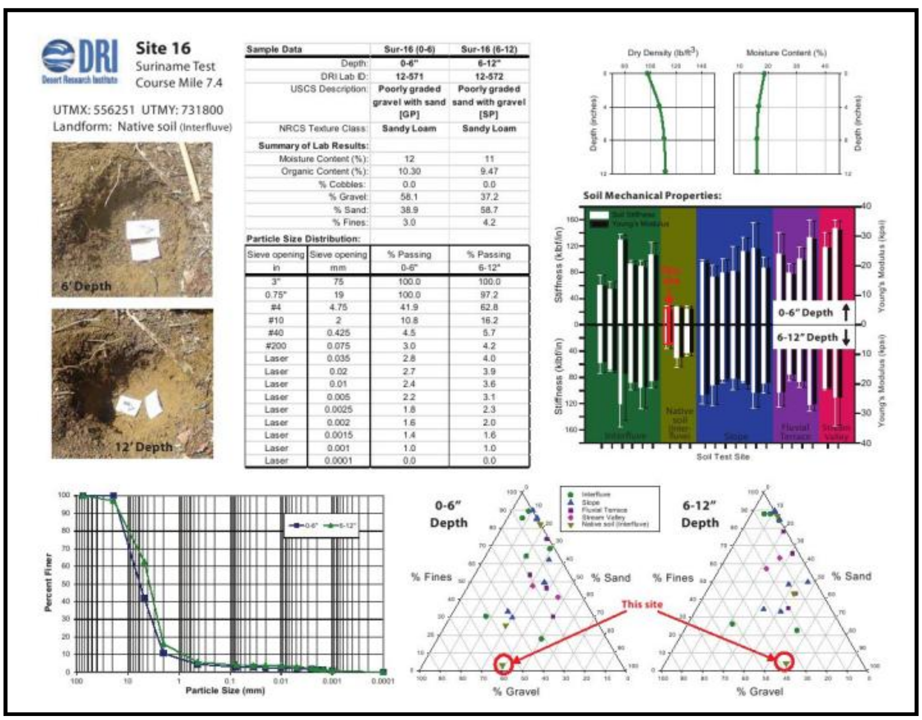


Figure C-11. Soil classification charts by Desert Research Institute Site 16 at Afobaka Test Site.

APPENDIX C. TEST SITE PARAMETERS.

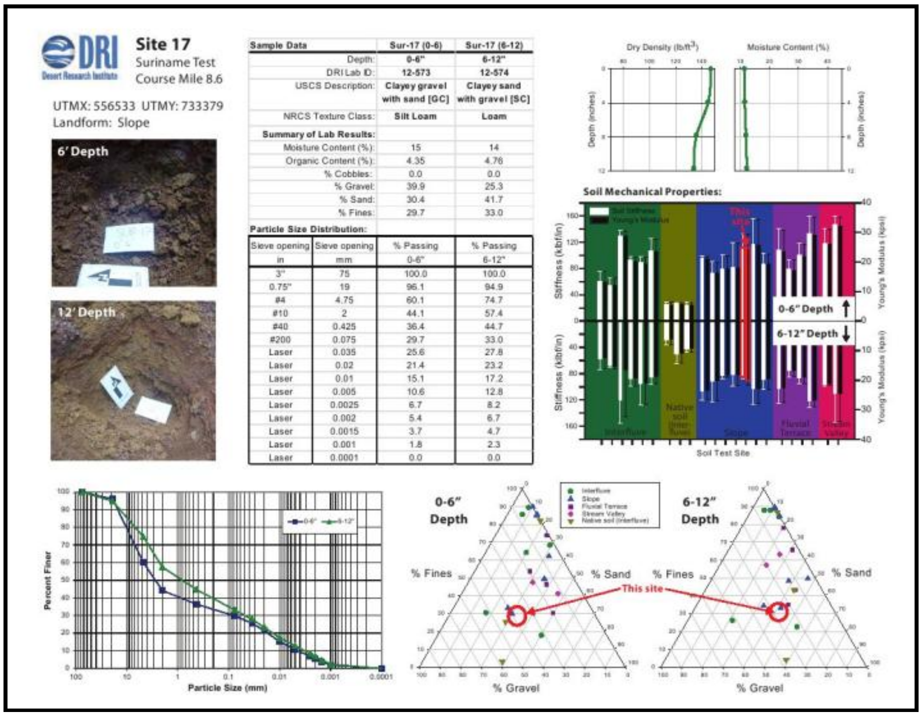


Figure C-12. Soil classification charts by Desert Research Institute Site 17 at Afobaka Test Site.

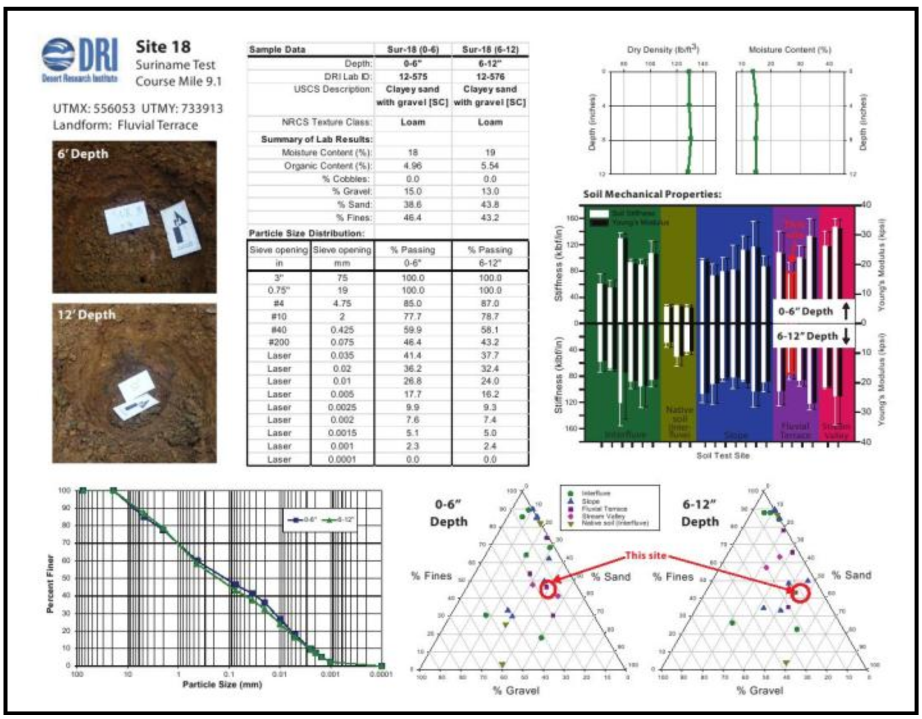


Figure C-13. Soil classification charts by Desert Research Institute Site 18 at Afobaka Test Site.

APPENDIX C. TEST SITE PARAMETERS.

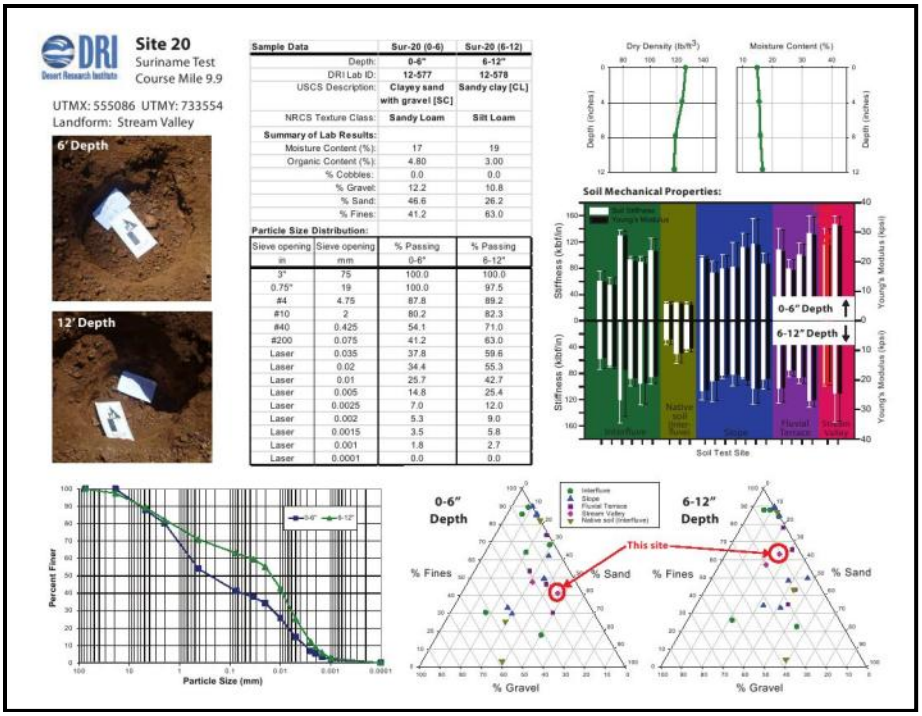


Figure C-14. Soil classification charts by Desert Research Institute Site 20 at Afobaka Test Site.

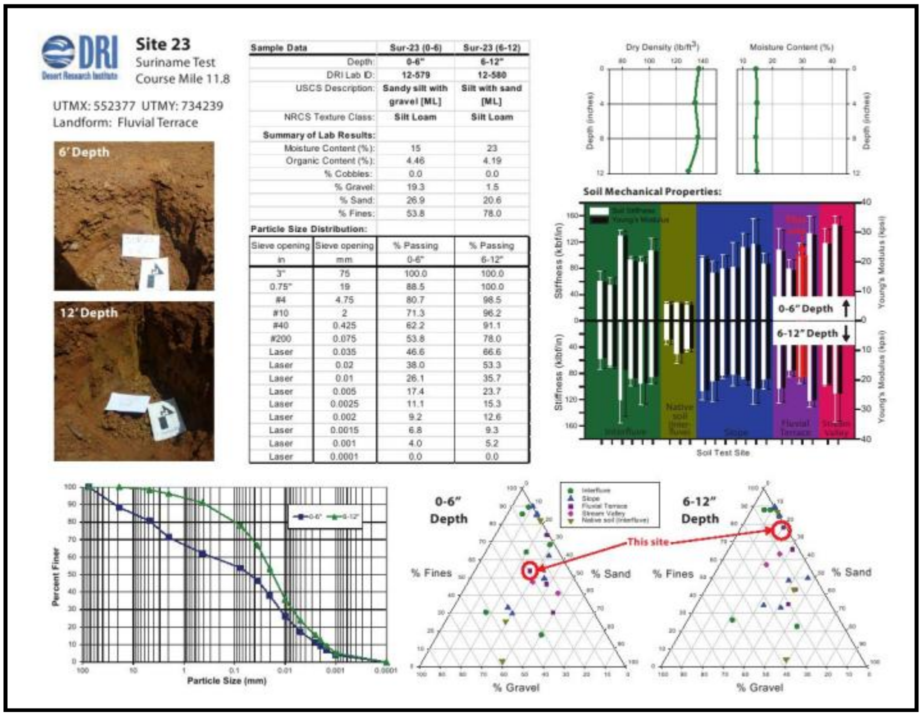


Figure C-15. Soil classification charts by Desert Research Institute Site 23 at Afobaka Test Site.

APPENDIX C. TEST SITE PARAMETERS.

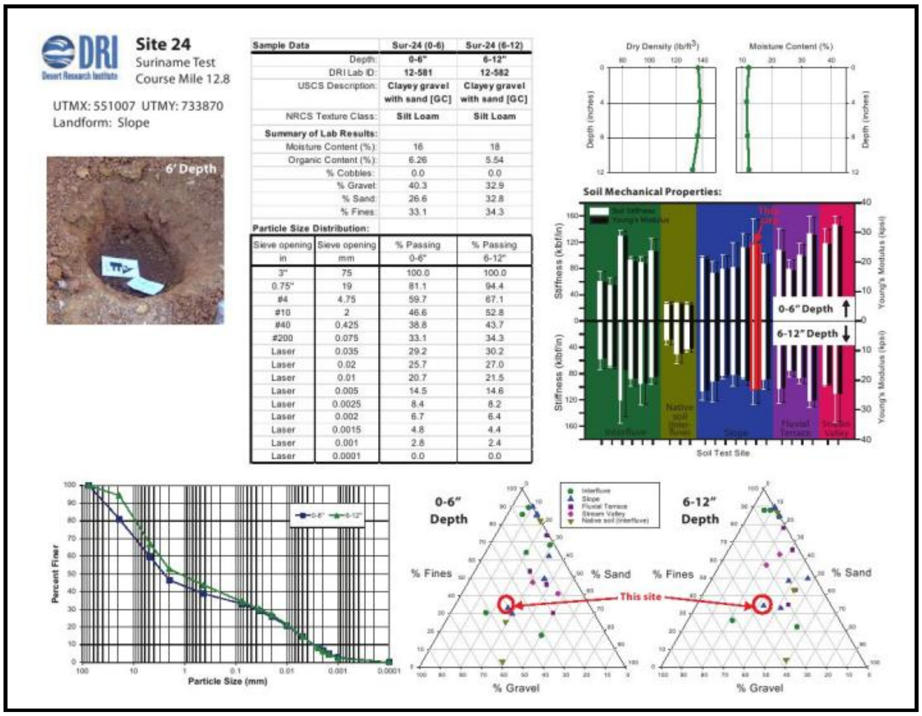


Figure C-16. Soil classification charts by Desert Research Institute Site 24 at Afobaka Test Site.

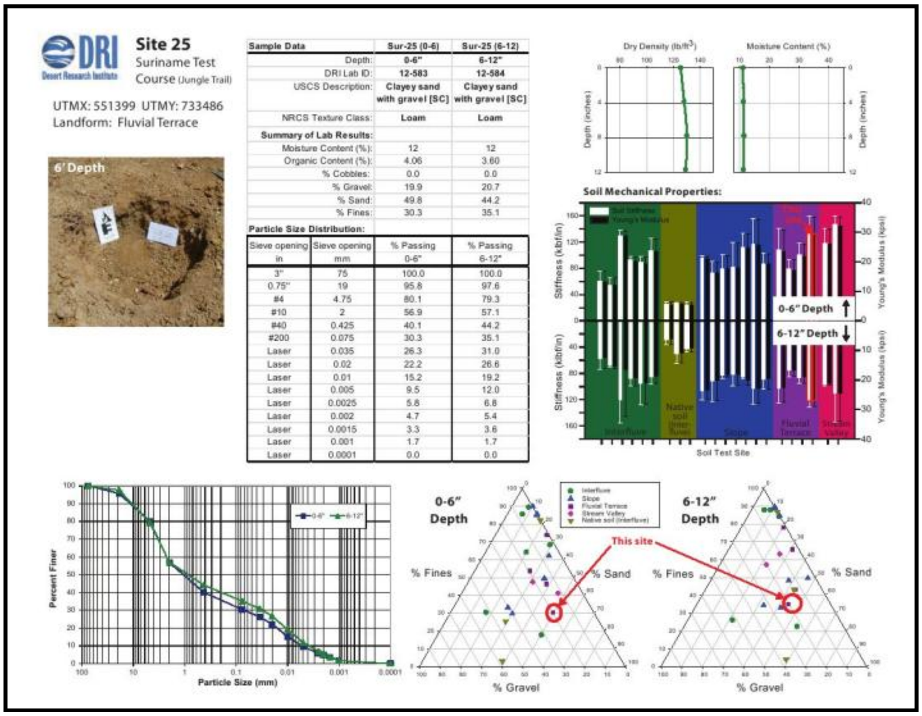


Figure C-17. Soil classification charts by Desert Research Institute Site 25 at Afobaka Test Site.

APPENDIX C. TEST SITE PARAMETERS.

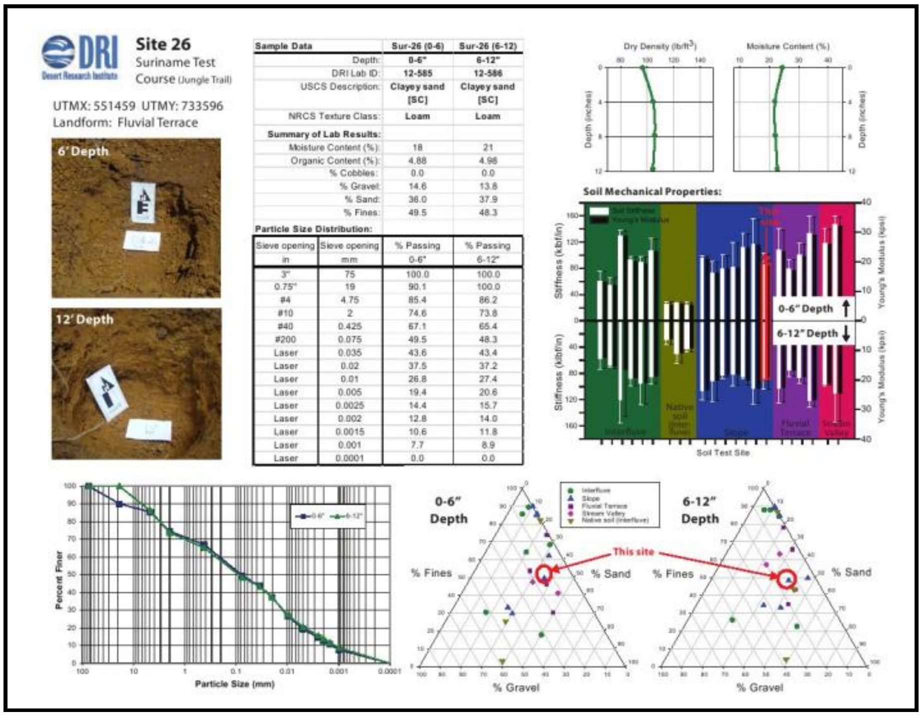


Figure C-18. Soil classification charts by Desert Research Institute Site 26 at Afobaka Test Site.

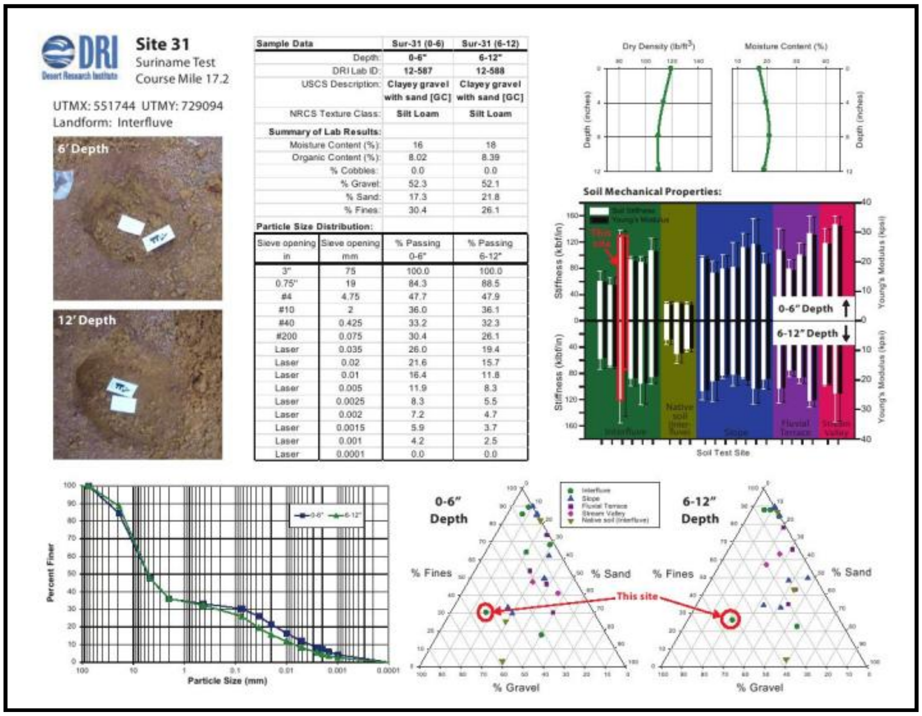


Figure C-19. Soil classification charts by Desert Research Institute Site 31 at Afobaka Test Site.

APPENDIX C. TEST SITE PARAMETERS.

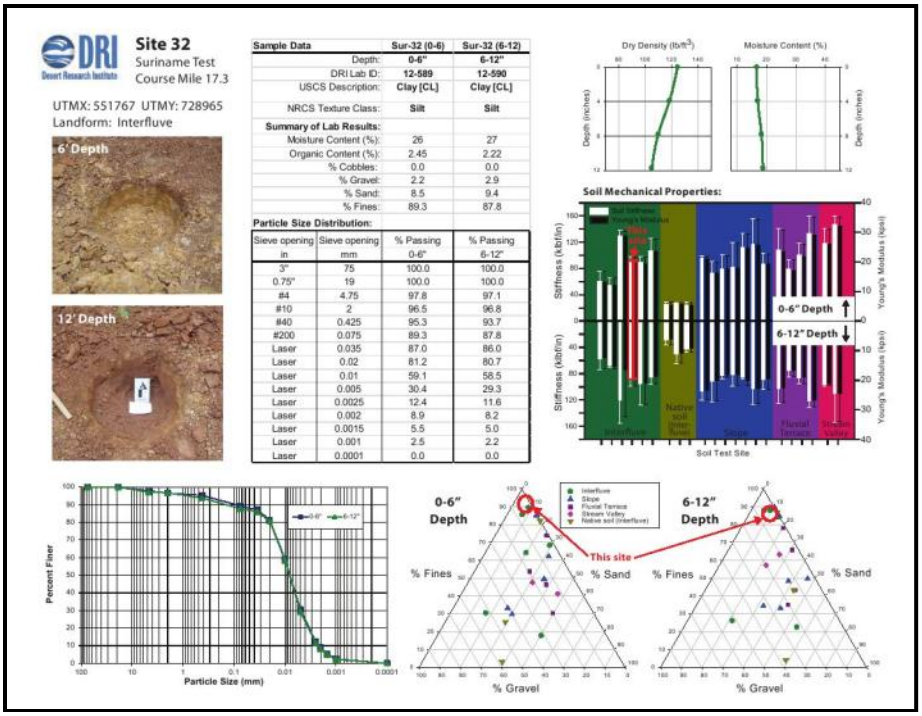


Figure C-20. Soil classification charts by Desert Research Institute Site 32 at Afobaka Test Site.

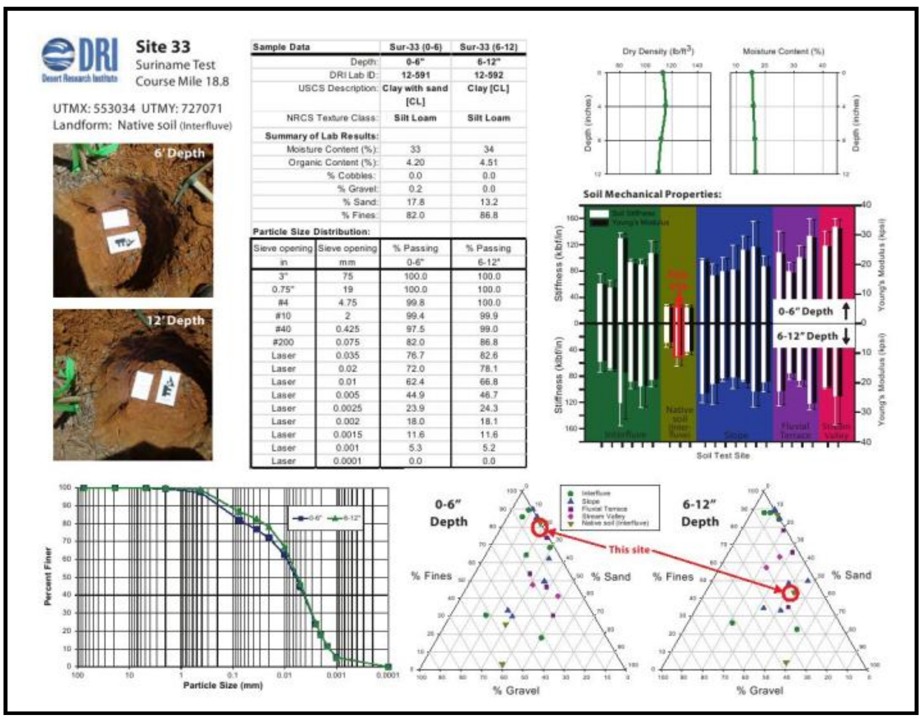


Figure C-21. Soil classification charts by Desert Research Institute Site 33 at Afobaka Test Site.

APPENDIX C. TEST SITE PARAMETERS.

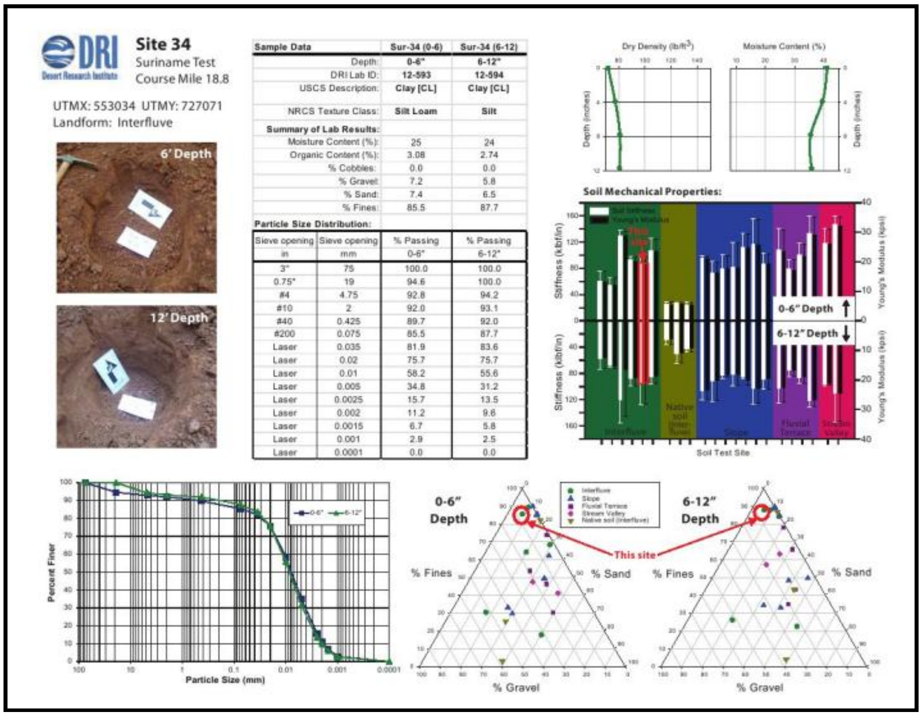


Figure C-22. Soil classification charts by Desert Research Institute Site 34 at Afobaka Test Site.

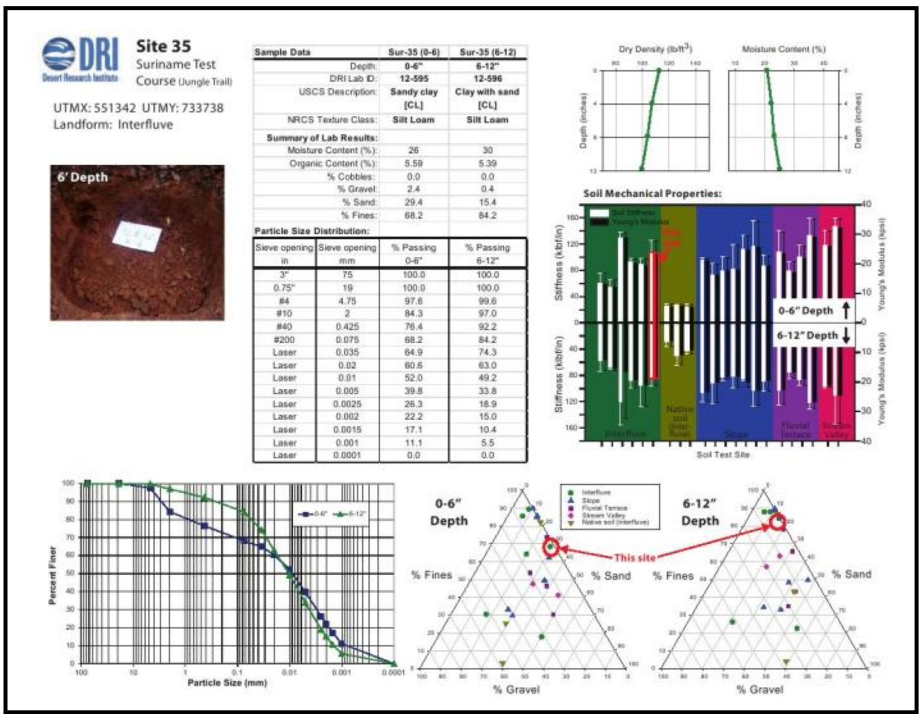
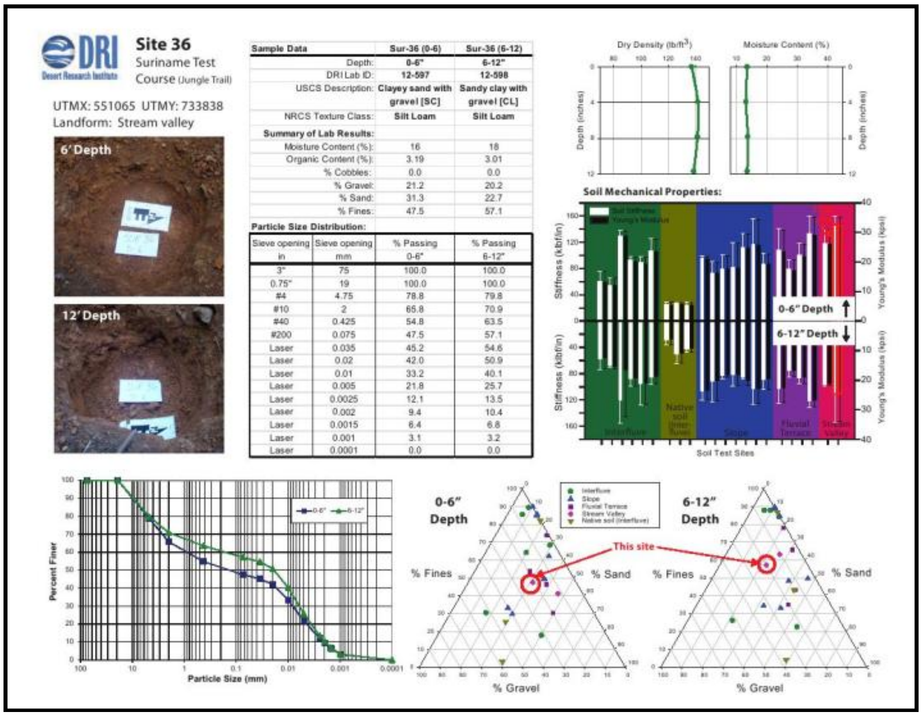


Figure C-23. Soil classification charts by Desert Research Institute Site 35 at Afobaka Test Site.

APPENDIX C. TEST SITE PARAMETERS.

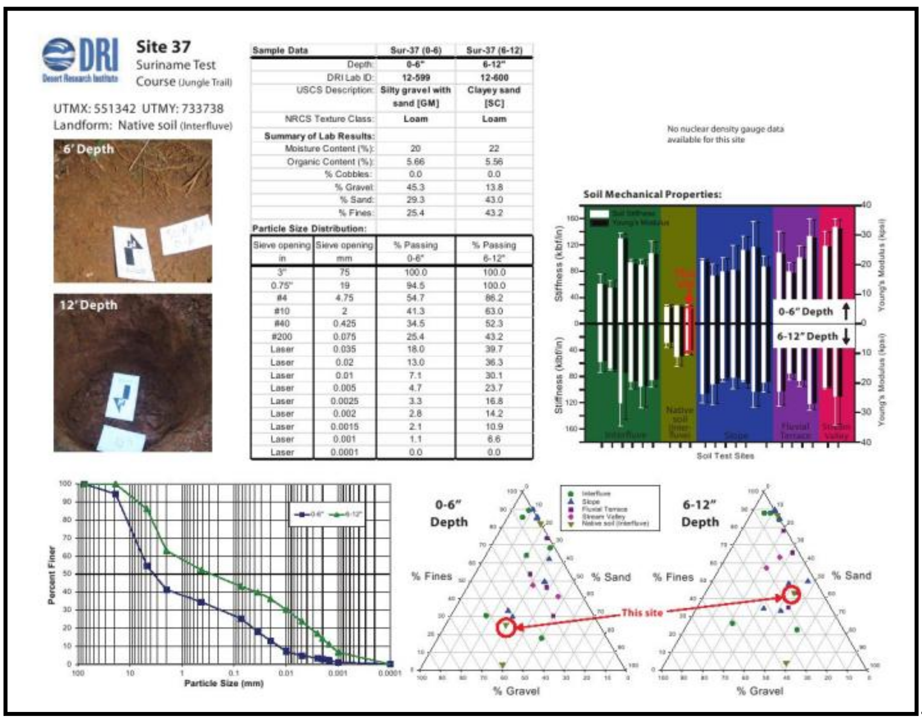


Sample Data	Sur-36 (0-6)	Sur-36 (6-12)
Depth:	0-6"	6-12"
DRI Lab ID:	12-597	12-598
USCS Description:	Clayey sand with gravel [SC]	Sandy clay with gravel [CL]
NRCS Texture Class:	Silt Loam	Silt Loam
Summary of Lab Results:		
Moisture Content (%):	16	18
Organic Content (%):	3.19	3.01
% Cobbles:	0.0	0.0
% Gravel:	21.2	20.2
% Sand:	31.3	22.7
% Fines:	47.5	57.1

Particle Size Distribution:

Sieve opening in	Sieve opening mm	% Passing 0-6"	% Passing 6-12"
3"	75	100.0	100.0
0.75"	19	100.0	100.0
#4	4.75	78.8	79.8
#10	2	65.8	70.9
#40	0.425	54.8	63.5
#200	0.075	47.5	57.1
Laser	0.035	45.2	54.6
Laser	0.02	42.0	50.9
Laser	0.01	33.2	40.1
Laser	0.005	21.8	25.7
Laser	0.0025	12.1	13.5
Laser	0.002	9.4	10.4
Laser	0.0015	6.4	6.8
Laser	0.001	3.1	3.2
Laser	0.0001	0.0	0.0

Figure C-24. Soil classification charts by Desert Research Institute Site 36 at Afobaka Test Site.



Sample Data	Sur-37 (0-6)	Sur-37 (6-12)
Depth:	0-6"	6-12"
DRI Lab ID:	12-599	12-600
USCS Description:	Silty gravel with sand [GM]	Clayey sand [SC]
NRCS Texture Class:	Loam	Loam
Summary of Lab Results:		
Moisture Content (%):	20	22
Organic Content (%):	5.66	5.56
% Cobbles:	0.0	0.0
% Gravel:	45.3	13.8
% Sand:	29.3	43.0
% Fines:	25.4	43.2

Particle Size Distribution:

Sieve opening in	Sieve opening mm	% Passing 0-6"	% Passing 6-12"
3"	75	100.0	100.0
0.75"	19	94.5	100.0
#4	4.75	54.7	86.2
#10	2	41.3	63.0
#40	0.425	34.5	52.3
#200	0.075	25.4	43.2
Laser	0.035	18.0	39.7
Laser	0.02	13.0	36.3
Laser	0.01	7.1	30.1
Laser	0.005	4.7	23.7
Laser	0.0025	3.3	16.8
Laser	0.002	2.8	14.2
Laser	0.0015	2.1	10.9
Laser	0.001	1.1	6.6
Laser	0.0001	0.0	0.0

Figure C-25. Soil classification charts by Desert Research Institute Site 37 at Afobaka Test Site.

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APPENDIX D. ABBREVIATIONS.

AEC	U.S. Army Evaluation Center
ATEC	U.S. Army Test and Evaluation Command
CG	center of gravity
CI	cone index
CL	clay of low plasticity
cm	centimeter
CPF	contact pressure factor
DBH	diameters at chest height
GR	grasses
kg	kilogram
m	meter
MI	mobility index
mN	millinewton
MXSG	mixed secondary growth
psi	pounds per square inch
RCI	rating cone index
RI	remolding index
SC	clayey sand
SR	Safety Release
TOP	Test Operations Procedure
TSARC	Test Schedule and Review Committee
USCS	Unified Soil Classification System
UTM	Universal Transverse Mercator
VCI	vehicle cone index

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APPENDIX E. REFERENCES.

1. Blades, Roy E., Environmental Mapping of Tropic Test Sites, ATEC Project No. 9-C0-009-000-013, 1972.

2. B. R. Davis, M. D. Neptune, and M. A. Johnson, Mobility in Natural Environments, Report I, Vegetation Override Test Methods, ATEC Project No. 9-CO-009-000-015, 1974.

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APPENDIX F. APPROVAL AUTHORITY.

CSTE-TM 27 August 2014

MEMORANDUM FOR

Commanders, All Test Centers
Technical Directors, All Test Centers
Directors, U.S. Army Evaluation Center
Commander, U.S. Army Operational Test Command

SUBJECT: Test Operations Procedure (TOP) 02-2-817A, Tropic Testing of Vehicles, Approved for Publication

1. TOP 02-2-817A, Tropic Testing of Vehicles, has been reviewed by the U.S. Army Test and Evaluation Command (ATEC) Test Centers, the U.S. Army Operational Test Command, and the U.S. Army Evaluation Center. All comments received during the formal coordination period have been adjudicated by the preparing agency. The scope of the document is as follows:

This TOP establishes procedures for conducting ground mobility subtests concerned with the interactions between the vehicle and soil, surface geometry, and vegetation in a humid tropic environment. These procedures can be applied with appropriate modifications to other environments.

2. This document is approved for publication and has been posted to the Reference Library of the ATEC Vision Digital Library System (VDLS). The VDLS website can be accessed at https://vdls.atc.army.mil/.

3. Comments, suggestions, or questions on this document should be addressed to U.S. Army Test and Evaluation Command (CSTE-TM), 2202 Aberdeen Boulevard-Third Floor, Aberdeen Proving Ground, MD 21005-5001; or e-mailed to usarmy.apg.atec.mbx.atec-standards@mail.mil.

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MICHAEL J. ZWIEBEL
Director, Test Management Directorate (G9)

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